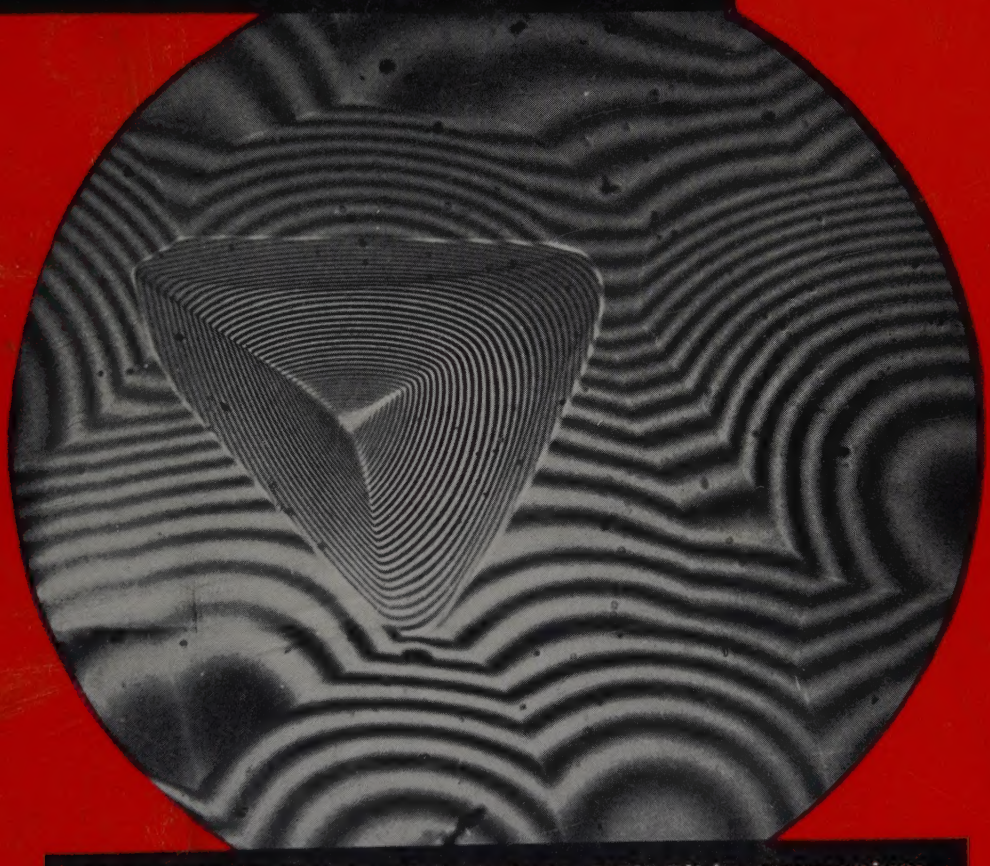
Sept./Oct. 1958
75c.

EMICONDUCTOR PRODUCTS



Microinterferogram of a surface etch pit in germanium.

se Current Feedback in
Transistor Power Amplifier Design

nsistor Bilateral Switches, Part 2

junction Transistor Test Set

HIGH BETA

130 at 1 amp
30 at 5 amps

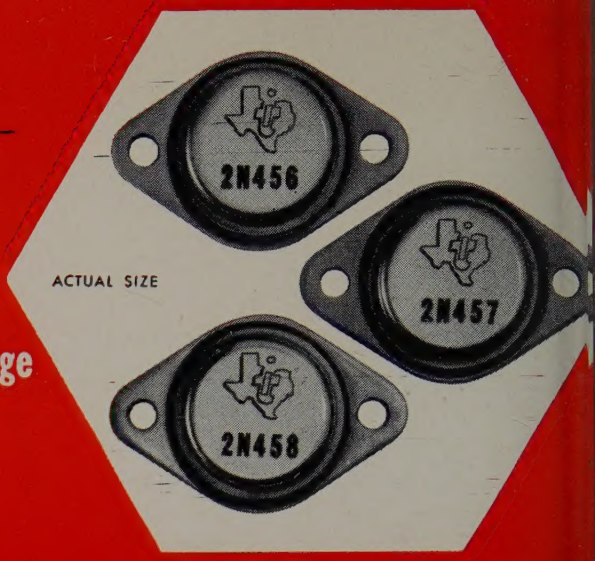
V_{CBO} -40V, -60V, or -80V

LOW

I_{CO} 2mA max at rated voltage

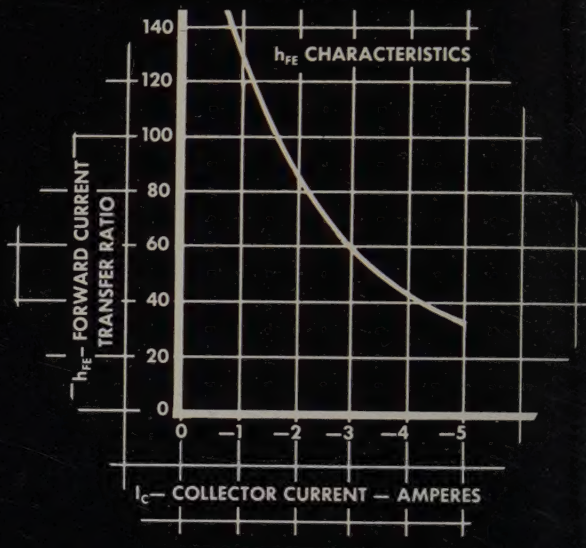
R_{CS} less than .05 ohms

T/I GERMANIUM POWER TRANSISTORS



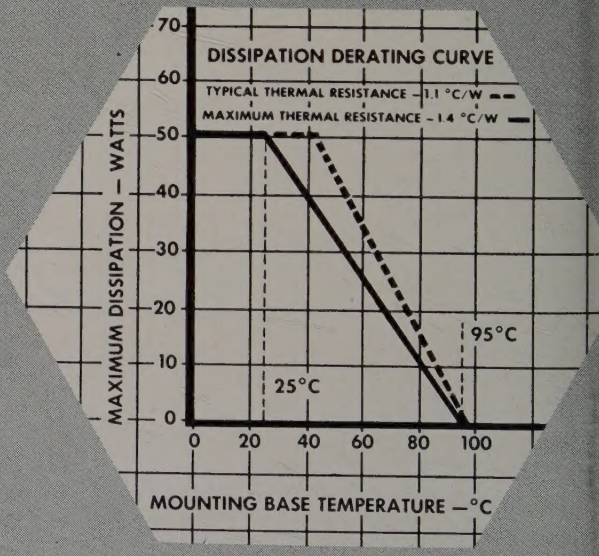
You get high current gain and power output with linear transconductance and extremely low distortion when you specify TI PNP germanium power transistors. Assurance of performance as specified results from checking I_{CO} at half as well as full rated voltage, and by checking beta again at low voltage ($V_{CE} = 1.5V$) and at two current ratings (1 amp and 5 amps). Ideally suited for your audio amplifier, current switching, and power conversion applications, TI 2N456, 2N457, and 2N458 germanium power transistors dissipate 50 watts with —40, —60, and —80V_{CBO} ratings . . . BV_{CBO} ratings average 20 volts higher for each transistor.

Check the specifications below for the unit most appropriate to your particular requirements.



maximum ratings at 25° C*		2N456	2N457	2N458	unit
V_{CBO}	Collector to Base ($I_C = -2.0mA$)	—40	—60	—80	V
V_{CEX}	Collector to Emitter ($V_{BE} = +0.2V$, $I_C = -2.0mA$)	—40	—60	—80	V
V_{EBO}	Emitter to Base ($I_E = -2.0mA$)	—20	—20	—20	V
	Total Dissipation†	50	50	50	W
I_C	Collector Current	5	5	5	A
I_B	Base Current	3	3	3	A
T_j	Junction Temperature	95	95	95	°C
typical characteristics at 25° C*					
BV_{CBO}	Collector to Base Breakdown Voltage ($I_C = -10mA$, $I_E = 0$)	—60V	—80	—100	V
h_{FE}	Forward Current Transfer Ratio ($I_C = -1.0A$, $V_{CE} = -1.5V$)	130	130	130	—
	($I_C = -5.0A$, $V_{CE} = -1.5V$)	30	30	30	—
R_{CS}	Common-Emitter Saturation Resistance ($I_C = -5.0A$, $I_B = -1.0A$)	0.048	0.048	0.048	Ohm
	Thermal Resistance from Collector Junction to Mounting Base	1.1	1.1	1.1	°C/W

* Temperature is measured on mounting base.
† For operation at higher temperatures refer to the Derating Curve.



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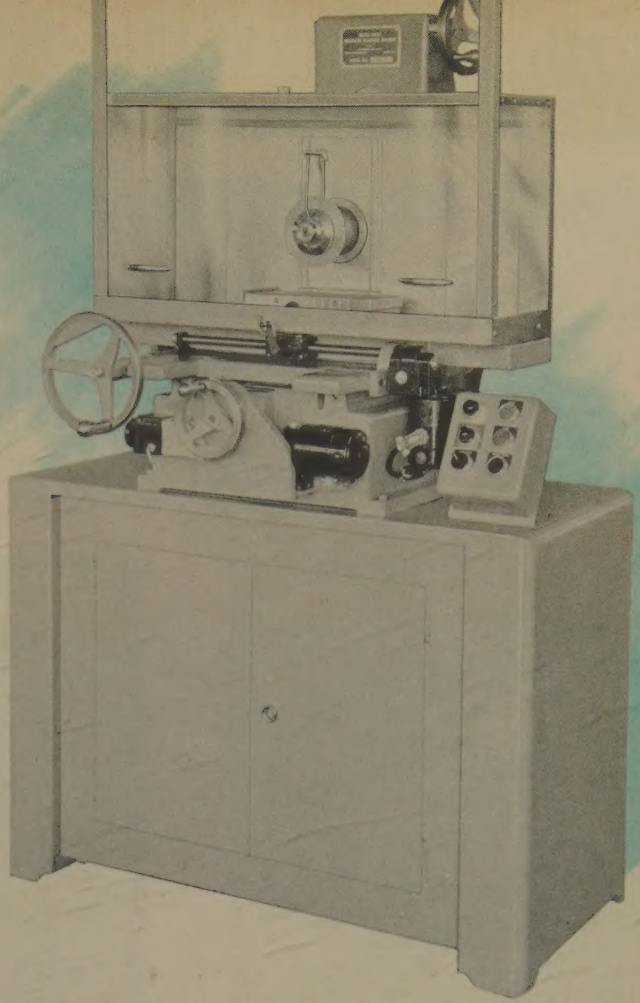

Micro-Matic Precision Wafering Machine—Fully Automatic Model WMA with repetitive indexing facilities. Using a 4", 5" or 6" diamond wheel, it produces wafers consistent in thickness and parallelism to within .0005" total variation. Semi-automatic models also available.

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ARE DESIGNED FOR VERY THIN SLICING AND DICING OF SEMI-C DUCTORS AS WELL AS OTHER HARD, DIFFICULT-TO-CUT MATERIA A FINE, BASIC MACHINE TOOL DESIGN PLUS A UNIQUE CONTR SYSTEM INSURE THE HIGHEST DEGREE OF PRECISION AND ECONOM

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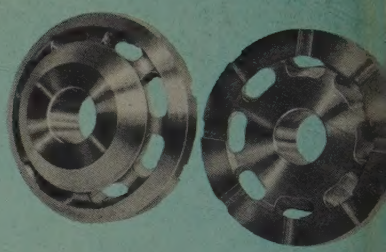
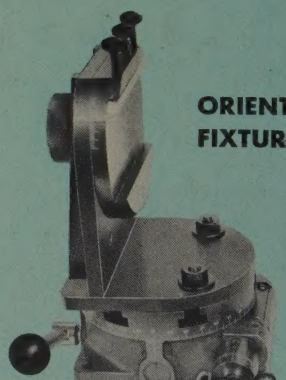


Used in conjunction with a single diamond cutting wheel to supply coolant at the point of contact between the wheel and the work.

ORIENTATION FIXTURES



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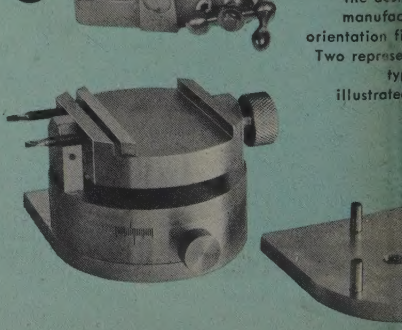

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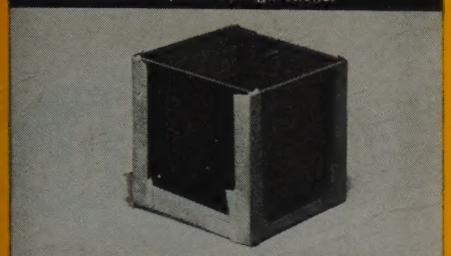

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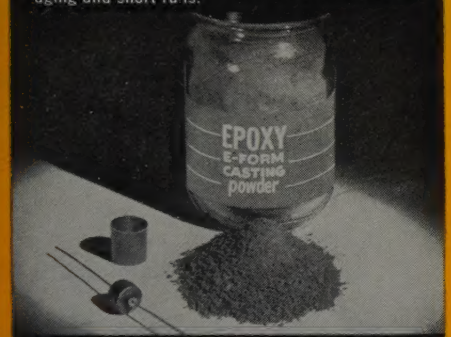

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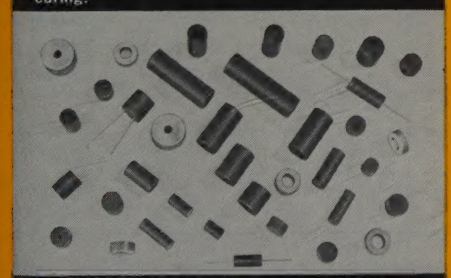

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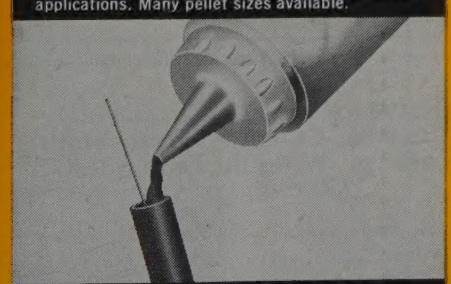

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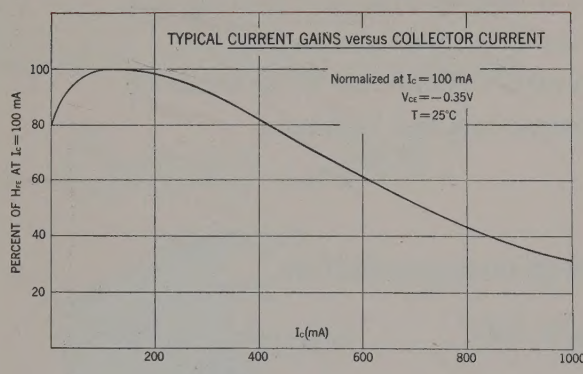
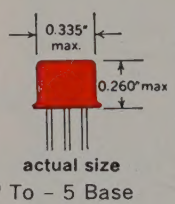
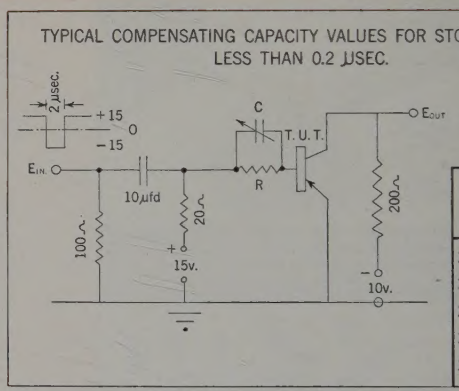
RELIABLE COMPUTER TRANSISTORS







Type	R kil-ohms
2N658	3.9
2N659	6.0
2N660	9.1
2N661	12.5
2N662	4.5

Type	Punch through Voltage max.	$f_{\alpha b}$ ave. Mc	H_{FE_1} ave. $I_B = 1$ mA $V_{CE} = -0.25$v	H_{FE_2} ave. $I_B = 10$ mA $V_{CE} = -0.35$v	I_{CO} at −12v μA	r_b' $I_C = -1$mA ohms	C_{ob} $V_{CB} = -6$v μμf
2N658	−24	5	50	40	2.5	60	12
2N659	−20	10	70	55	2.5	65	12
2N660	−16	15	90	65	2.5	70	12
2N661	−12	20	120	75	2.5	75	12
2N662	−16	8	30 min.	50	2.5	65	12

Typical values at 25°C unless otherwise indicated

Dissipation Coefficients: In air 0.35°C/mW; Infinite Sink 0.18°C/m

These new PNP Germanium Computer Transistors made by Raytheon's reliable *fusion-alloy* process add to the already comprehensive line of Raytheon Reliable Computer Transistors which include several in the *Submin* (0.160" high, 0.130" dia.) package. Write for Data Sheets.

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Sept./Oct. 1958 Vol. 1, No. 5

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Front Cover

Shown on the cover this month is a microinterferogram of a surface etch pit in germanium. This research technique, akin to topographic mapping, is used at Raytheon in basic studies of semiconductor materials. The specimen was photographed through a two-beam interference microscope which forms the interference pattern between the light reflected from the etched surface and that reflected from a mirror serving as the reference surface. A thallium spectrum tube served as a monochromatic light source with a wavelength of 21.2 microinches. Each band spacing represents 10.6 microinches. The deviations of the bands (in fractions of band spacings) indicate the depth of surface irregularities, like contour lines on a topographic map. These deviations thus permit a quantitative interpretation of the topography or profile of the detail being observed. Depth of etch pit shown is 300 microinches; magnification is 1200X.

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- SMALL SIZE
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For still higher voltages at currents to 175 ma, Transitron makes rectifier assemblies in cartridges and in the convenient "2 W" axial lead package.

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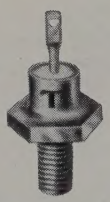

Type	Maximum Inverse Operating Voltage (volts)	Maximum Average Forward Current (ma)	Maximum Average Inverse Current @ Full Load (ma)
TM155	1500	400	.5
TM156	1500	200	.5
TM124	1200	1000	.5
TM125	1200	400	.5
TM126	1200	200	.5
TM104	1000	1000	.5
TM105	1000	400	.5
TM106	1000	200	.5

Transitron electronic corporation wakefield, massachusetts

Transistors Diodes Regulators Rectifiers

Editorial . . .

old Enterprise

The last two decades have proved that smugness and omplacency not only do not pay off but often result n loss of business and failure. Think of the many so-alled well established firms that have fallen by the vayside during this period—their business being aken over by comparatively new companies directed y men with boldness of enterprise!

The transistor is a most potent tool in the possession f the bold and with this tool they can explore count-ess avenues of new processes and applications. Tran-istors are both a threat and a promise to well-stablished firms using yesterday's components and ystems—a threat if these firms persist in burying heir heads in the sand and a promise of greater ex-ansion if they will make use of their established ositions and dedicate a substantial portion of their ndeavors to making greater use of transistors in their roducts.

Conventions

During the last few months of this year a number of rofessional meetings and symposiums on various hases of transistorization will take place throughout he country. Among these are the annual conference n Electrical Techniques in Medicine and Biology to e held at Minneapolis, Minnesota November 19-21 ponsored by IRE and AIEE; the 1958 Electronic Devices Meeting to be held at Washington, D. C., on October 30, 31, and November 1st sponsored by PGED of the IRE and the Eastern Joint Computer Conference to be held at Philadephia on December -5 sponsored PGEC of the IRE, AIEE and ACN. These conferences serve not only as a meeting place or the exchange of ideas among scientists and engi-eers, but often are the inspiration for spectacular roducts of the future. We believe that too much tress is placed on commercialism at these conferences t the expense of the interchange of technical infor-nation and suggest that management would serve

[*Continued on page 60*]

NEW GIANT
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Generator G-5001
500 watts output

Transducerized Tank NT-5001
Capacity: 10 gallons
Dimensions: 20" L x 11½" W x 10" D

Generator features tank selector and load selector switches on front panel to operate one or two NT-5001 tanks alternately. Other combinations of tanks and submersible transducers available from stock; larger tanks available on special order.

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For mass-production cleaning and high capacity chemical processing!

Here's a new Narda SonBlaster ultrasonic cleaner with tremendous cavitation activity and generating capacity! Featuring full 500 watts output, this SonBlaster is available with a fully transducerized giant 10-gallon capacity tank. In addition, it will operate from six to 10 Model NT-605 high energy submersible transducers, at any one time, in any arrangement in any shape tank you need up to 70-gallon volume.

Install this new Narda SonBlaster, and immediately you'll start chalking up savings over costly solvent, vapor or alkaline degreasing methods! You'll save on chemicals and solvents, cut maintenance and downtime, eliminate expensive installations, save on floor space, and release labor for other work. But perhaps most important, you'll clean faster, cut rejects, and eliminate bottlenecks.

Whether you're interested in mass-production cleaning or degreasing of mechanical, electronic, optical, or horological parts or assemblies ... rapid, quantity cleaning of "hot-lab" apparatus, medical instruments, ceramic materials, electrical components or optical and technical glassware ... or in speeding up metal finishing and chemical processing of all types—you'll find this new SonBlaster will do your work faster, better and cheaper. Write for more details now, and we'll include a free questionnaire to help determine the precise model you need. Address: Dept. SP-20.

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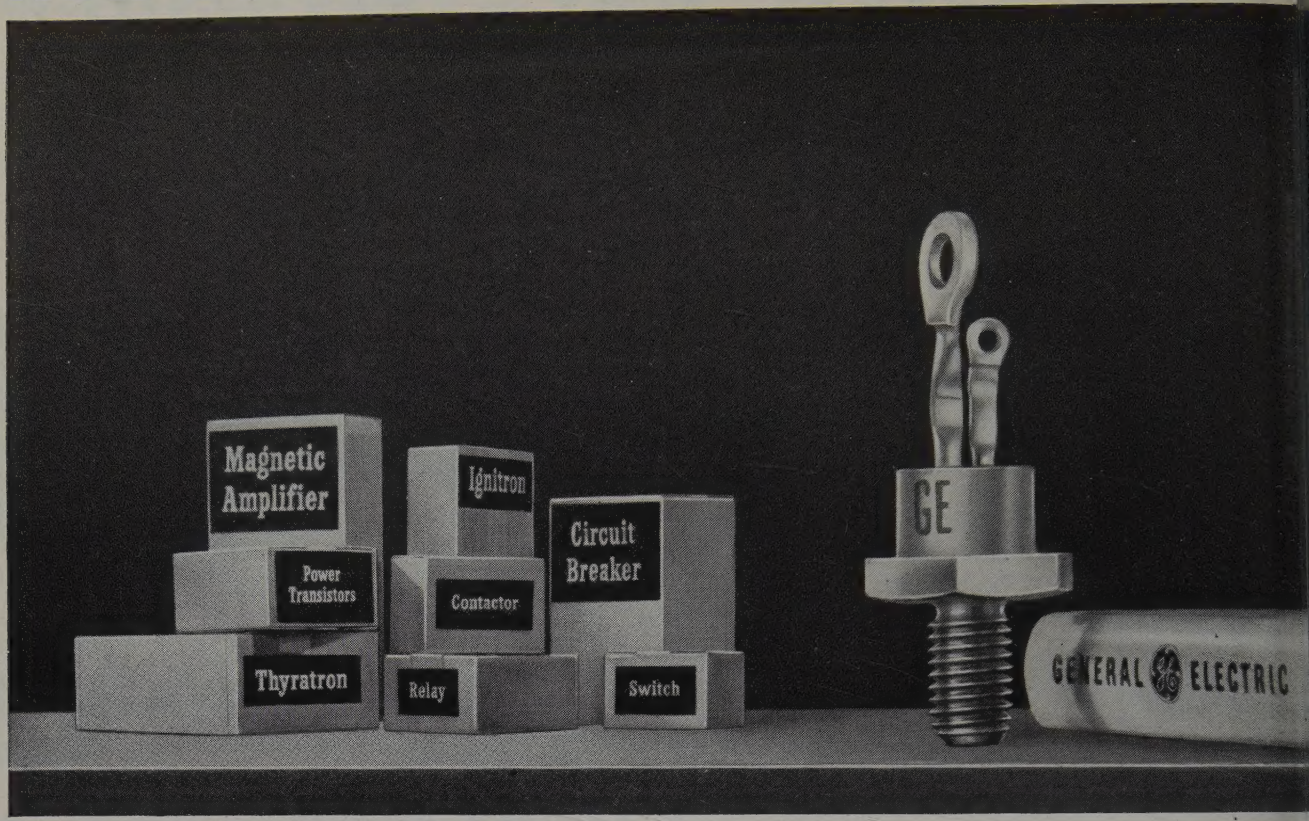
New controlled rectifier does all the



Maximum Allowable Ratings and Characteristics

(Resistive or Inductive Load)

	ZJ39A 25	ZJ39A 40	ZJ39A 75	ZJ39A 100	ZJ39A 150	ZJ39A 200	ZJ39A 250	ZJ39A 300
Continuous Peak Inverse Voltage (PIV)	25	40	75	100	150	200	250	300
Transient Peak Inverse Voltage (Non-recurrent > 5 millisec)	35	60	100	150	225	300	350	400
RMS Voltage (Vrms)	17.5	28	53	70	105	140	175	210
Average Forward Current (I_F)	Up to 16 amperes							
Peak One-cycle Surge Current (i surge)	150 amperes							
Minimum Forward Breakover Voltage (V_{BO})	25	40	75	100	150	200	250	300
Maximum Forward Voltage (V_F Ave.)	0.75 Volts (Full Cycle Average)							
Maximum Reverse Current (I_R)	5 ma (Full Cycle Average)							
Maximum Gate Current To Fire (I_{GF})	25 ma							
Maximum Gate Voltage To Fire (V_{GF})	3 Volts							

Finer performance of G-E low-current silicon rectifi now within reach for all your requirements

MAXIMUM RATINGS AND SPECIFICATIONS

	PIV	RMS Voltage	Cont. Reverse D-C Volt	D-C Output (150°C Amb.)	D-C Output (50°C Amb.)	One-cycle Surge Current	Full-Load Forward Voltage Drop	Leakage Current	Ambient Operating Temp.
1N536-40, 1N1095-96 series	50-600	35-420	50-600	250	750	15	0.5	0.4-0.3	165
1N440B-445B series	100-600	70-420	100-600	300-500 (100°C)	300-750	15	0.5		150-165
1N1487-92 series	100-600	70-420	100-600	250 (125°C)	750 (25°C)	15	0.55	0.3	140
1N1692-95 series	100-400	70-280	100-400	250 (100°C)	600 (50°C)	20	0.6	0.5	115
	volts	volts	volts	ma	ma	amps	volts	ma	°C

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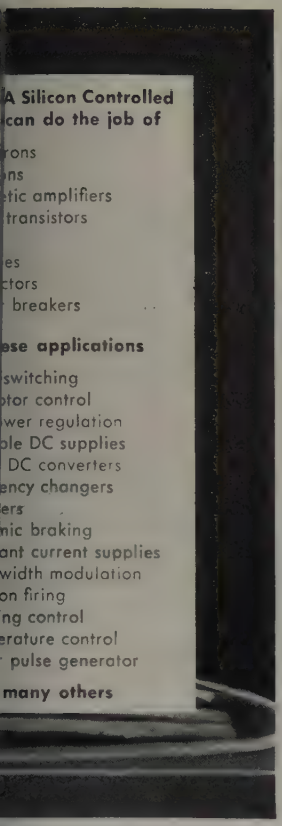

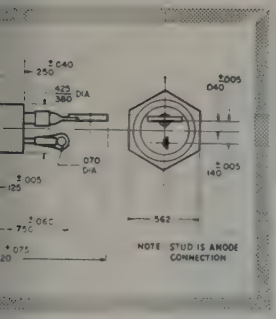

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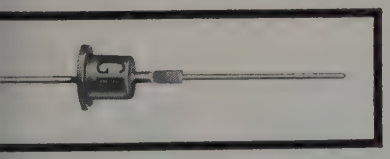

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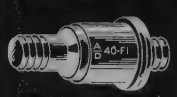

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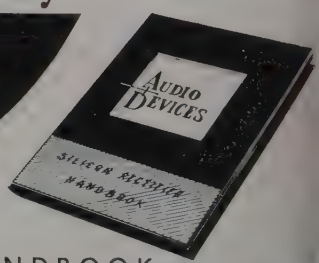

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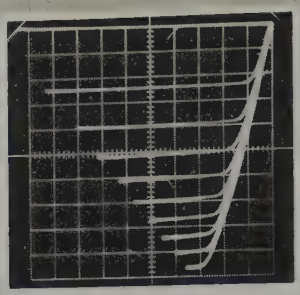
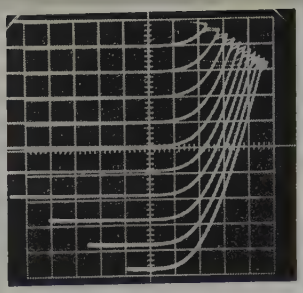


HIGH COLLECTOR CURRENT

PNP transistor, collector current vs collector voltage with constant-current base steps. Collector sweep is 0 to 5 v with a 0.25-ohm load, base current is 50 ma/step. Vertical deflection is 1000 ma/div, horizontal 0.5 v/div.



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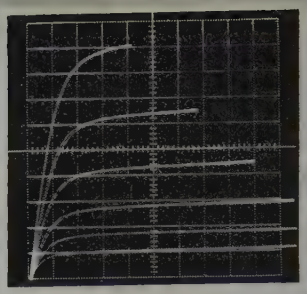
PNP transistor, collector current vs collector voltage with base grounded and constant-current emitter steps. Collector sweep is 0 to 1.5 v, emitter current 200 ma/step. Vertical deflection is 200 ma/div, horizontal 0.1 v/div. Zero voltage is at center scale.



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P_C	Total dissipation Case temp. 25° C. Case temp. 100° C.	2 watts 1 watt		
h_{FE}	D.C. current gain		2N696—15 to 30 2N697—30 min.	I_C=150ma V_C=10v
R_{CS}	Collector saturation resistance		6Ω typical, 10Ω max.	I_C=150ma I_B=15ma

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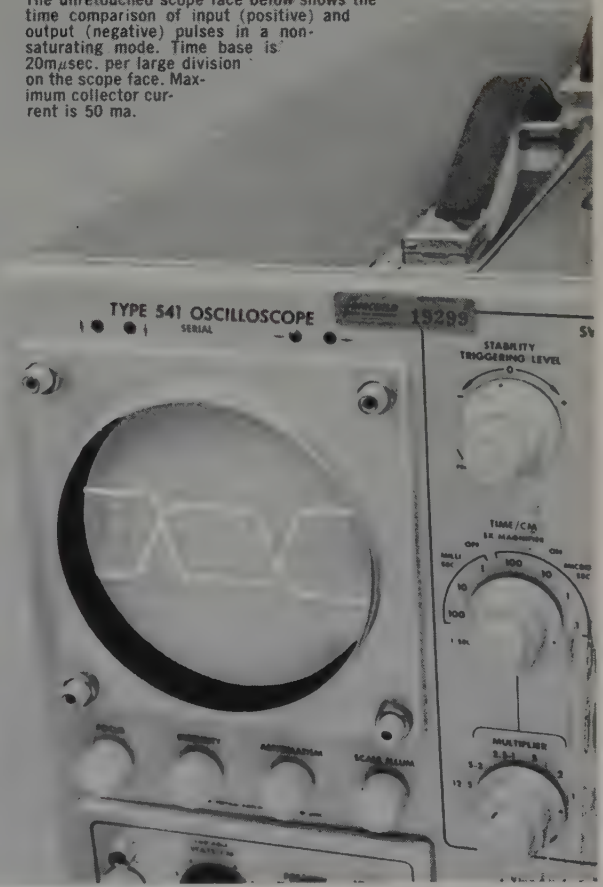
The unretouched scope face below shows the time comparison of input (positive) and output (negative) pulses in a non-saturating mode. Time base is 20mμsec. per large division on the scope face. Maximum collector current is 50 ma.



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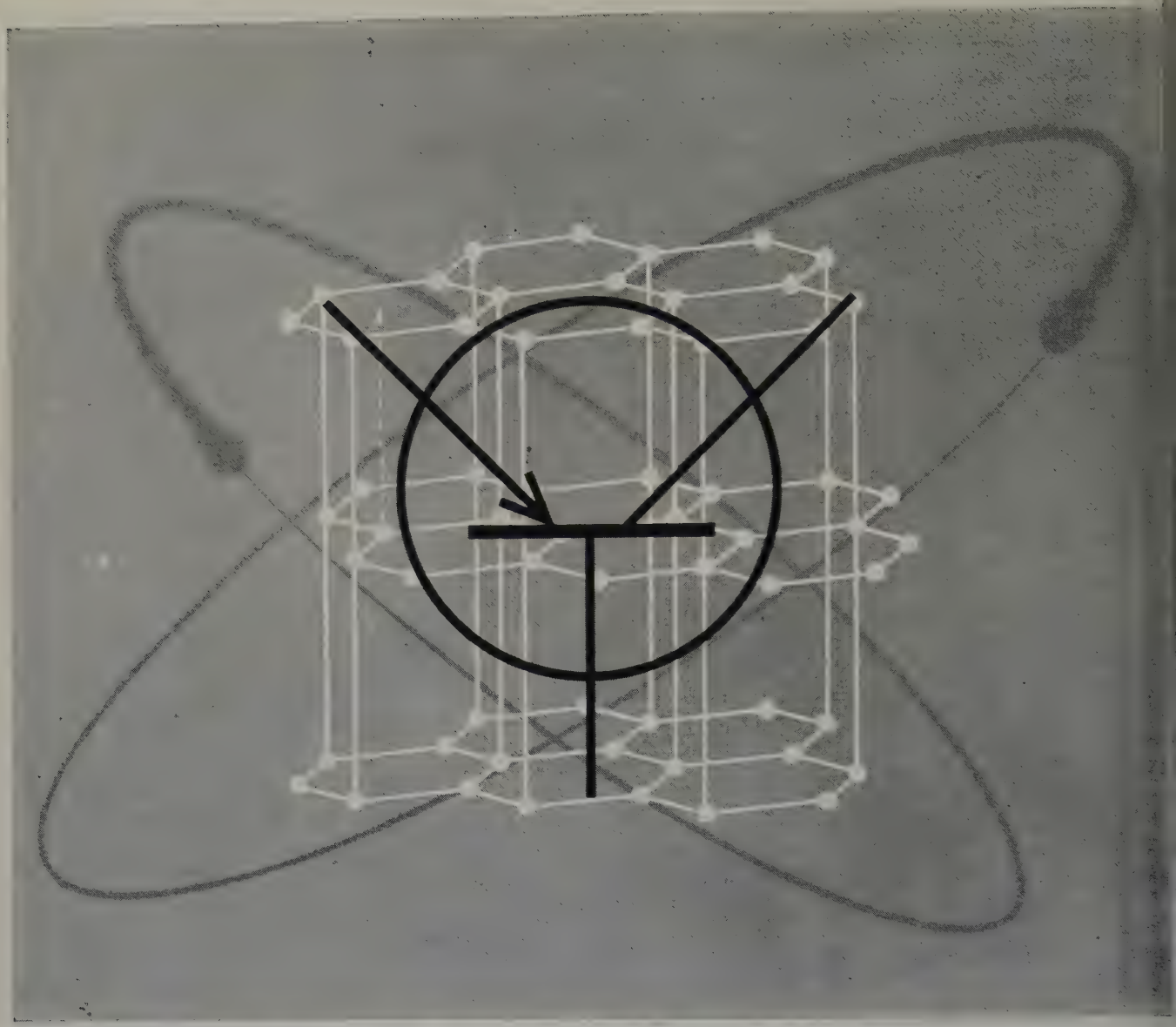

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Base Current Feedback and the Feedback Compound Transistor

DR. FRANK S. BOXALL

Base current feedback is a means for reducing the nonlinear distortion and frequency distortion resulting from variations in the emitter to collector current transfer ratio of transistors. The distortion is reduced by feeding the transistor base current back to the emitter terminal, and is accomplished without loss of gain and without incurring a stability problem. Output impedance is increased by the feedback. In Part I of this article, the theory of base current feedback is developed in terms of an amplifier in which the base current of a grounded base output stage is fed back to the emitter via the preamplifier. The distortion reduction depends upon the preamplifier transmission characteristic. A second possibility is to feed back the base current through a second grounded base transistor and the combination of the two is called a "feedback compound transistor." The current transfer ratio of the compound is almost exactly unity and is almost independent of variations in the current transfer ratio of the compounded transistor. In Parts II and III, the feedback compound transistor is treated as a single amplifying element in both common base and common emitter configurations. Classical feedback theory is used to demonstrate that the reduction in distortion due to emitter degeneration is much greater when the transistor is compounded than when it is not.

Part I: THEORY OF BASE CURRENT FEEDBACK

T IS well known that the imperfections of a power amplifier are due primarily to the imperfections of the final stage. Where a grounded base nsistor is used for the final stage amplifying elent, as in *Fig. 1* there are essentially three mechams whereby the final stage degrades the amplifier formance. These are the variations with signal plitude (nonlinear distortion) or frequency (freency) distortion of

(1) The transistor input impedance
(2) The transistor short circuit current gain, α
(3) The transistor open circuit output impedance, Z_o

he output impedance of the preamplifier is made ficiently large, the current injected into the final ge is essentially independent of its input impedee and the degradation of amplifier performance to the first factor listed above can be reduced by s means.[1] The second and third factors listed above y be considered jointly as current transfer distorn inasmuch as the current transfer ratio (loaded rent gain) of the final stage is

$$\frac{i_o}{i_e} = \alpha_L = \frac{\alpha}{1 + \frac{Z_L}{Z_o}} \qquad (1)$$

ere Z_L is the load impedance.

ork done while in employ of Lenkurt Elec. Co., Inc., San los, Calif. Now with Hewlett Packard Co., Palo Alto, Calif.
s point is considered in detail in Part II.

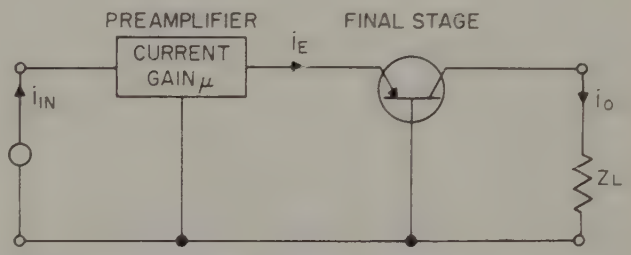


Fig. 1—Power amplifier with grounded base transistor final stage.

In order to focus attention on final stage transfer distortion it will be assumed that the preamplifier is distortionless with high output impedance, so that the final stage input current is exactly μ times the preamplifier input current. In this case the current gain and output impedance of the amplifier of *Fig. 1* are

$$G = \mu \alpha_L$$

$$Z_{out} = Z_o$$

and all of the distortion is due to final stage transfer distortion. If the final stage transistor output current were exactly proportional (say equal) to its input current, there would be no transfer distortion and the amplifier would be essentially perfect. It should be noted, therefore, that the difference between these two currents is simply the transistor base current. Because this current is a direct measure of the amplifier imperfection, and is readily available at the transistor base terminal, it can be utilized to improve the amplifier performance. A fairly obvious suggestion is to combine the base current with the collector cur-

rent so that the sum flows through the load. However this scheme is difficult to realize in practice without appreciable loss of base current.[2] A less obvious but more effective scheme is to feed the base current back to the emitter, using the preamplifier to make up any loss of base current which may occur in the feedback network. Such an arrangement is shown in *Fig. 2*, wherein the base current is fed back to the preamplifier input through a passive network of current transfer ratio β which should have an optimum value of

$$\beta = \frac{1}{\mu} \tag{2}$$

In the amplifier of *Fig. 2*,

$$i_b = i_e - i_o \tag{3}$$

$$i_e = \mu\,(i_{in} + \beta i_b) \tag{4}$$

$$i_o = \alpha_L i_e \tag{5}$$

where α_L is given by equation (1). Eliminating i_b from equations (3) and (4), and substituting i_e from equation (5) yields

$$\frac{i_o}{i_{in}} = G' = \mu\,\alpha'_L \tag{6}$$

where

$$\alpha'_L = \frac{\alpha_L}{1 - \mu\beta\,(1 - \alpha_L)} \tag{7}$$

Substituting equation (1) into equation (7) yields

$$\alpha'_L = \frac{\alpha'}{1 + \dfrac{Z_L}{Z'_o}} \tag{8}$$

where

$$\alpha' = \frac{\alpha}{1 - \mu\beta\,(1 - \alpha)} \tag{9}$$

$$Z'_o = Z_o \frac{1 - \mu\beta\,(1 - \alpha)}{1 - \mu\beta} \tag{10}$$

Equations (6) through (10) demonstrate that the application of base current feedback to an amplifier can be considered equivalent to replacing the final stage transistor by a new transistor having short circuit current gain and open circuit output impedance given by equations (9) and (10). The current gain and output impedance of the amplifier are

$$G' = \mu\,\alpha'_L$$

$$Z'_{out} = Z'_o$$

In particular, when β has the value given by equation (2),

$$\alpha' = 1$$

$$Z'_o = \text{infinity}$$

$$\alpha'_L = 1$$

$$G' = \mu$$

$$Z'_{out} = \text{infinity}\ ^{3}$$

In this case α' and Z'_o are independent of α and Z hence the transfer distortion of the final stage h been completely eliminated.

This considerable improvement in performance obtained with no loss of gain and without incurring stability problem, since the current gain around t feedback loop is

$$\text{Loop Gain} = \mu\beta\,(1 - \alpha_L)$$

which is less than unity, being essentially equal to t current transmission from emitter to base of t power transistor. It should also be noted that the opt mum adjustment of β is independent of the final sta transistor parameters. Because the base current is re turned to the emitter via the preamplifier, the ampl fier gain becomes slightly more sensitive to preampl fier gain. The percent change in G' due to a one per cent change in μ is obtained by differentiating equa tion (6) to obtain

$$\frac{dG'}{G'} \Big/ \frac{d\mu}{\mu} = \frac{\alpha'_L}{\alpha_L}$$

which is only slightly greater than unity and is not significant penalty.

In practice the value of β will differ somewhat fro the optimum value of equation (2), and there will b distortion in the output. The amount of this distortio may be calculated by representing the transistor cur rent transmission by

$$i_o = a\,i_e + d \tag{11}$$

where a is a constant. Thus the first term represent that portion of the output current which is exactl proportional to the emitter current (no distortion) and the second term represents the current transfe distortion (either nonlinear or frequency distortio depending upon the consideration of interest). Elimi nating i_b from equations (3) and (4) and substitutin for i_e from equation (11) yields

$$i_o = \frac{a\,\mu\,i_{in} + (1 - \mu\beta)\,d}{1 - \mu\beta\,(1 - a)}$$

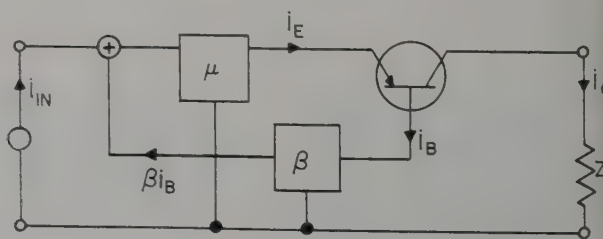


Fig. 2—Power amplifier with base current feedback applied.

[2] In the Darlington compound transistor connection, a second transistor is used as the combining network.

[3] If required, the amplifier output impedance can be matched to the load impedance by applying 6 db of negative feedback derived from the output voltage.

id the per unit output distortion is

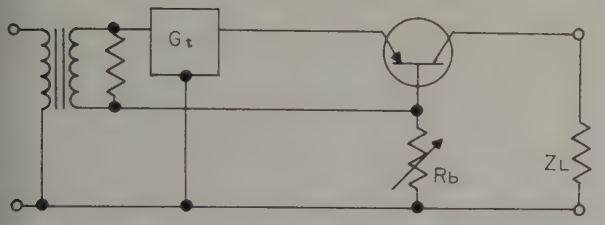
$$D' = \frac{(1 - \mu\beta)\, d}{a\, \mu\, i_{in}}$$

his should be compared to the per unit output distor-
on obtained without base current feedback ($\beta = 0$)
id under the condition that the nondistorted outputs
ave the same magnitude in the two cases. The result

$$D' = \frac{1 - \mu\beta}{1 - \mu\beta\,(1 - a)}\, D$$

here D is the per unit output distortion without base
urrent feedback. For typical values of α and $\mu\beta$ the
enominator is close to unity and, to a good approxi-
ation the distortion improvement due to base cur-
ent feedback is

$$I = 20 \log_{10} \frac{1}{|1 - \mu\beta|} \text{ db}$$



ig. 3—A practical realization of base current feedback.

hus, in the $\mu\beta$ plane loci of constant improvement
re concentric circles centered at $1 + j0$ of radius

$$r = 10^{-\frac{I}{20}}$$

particular, if $\mu\beta$ has a magnitude of unity and a
ase shift of θ, the improvement is

$$I = -20 \log_{10}\left(\sin\frac{\theta}{2}\right) - 6 \text{ db}$$

$$\cong -20 \log_{10} \theta \text{ (for small } \theta \text{ in radians)} \qquad (12)$$

It is apparent that if large improvements are to be
aintained over wide bandwidths the preamplifier
ansmission must be closely controlled. For this rea-
n it is suggested that the preamplifier be designed
ing conventional negative feedback (current feed-
ck to maintain high output impedance), such that

$$\mu = \frac{\mu_o}{1 - \beta_o\, \mu_o}$$

here μ_o and β_o are respectively, the preamplifier
in without feedback and the conventional feedback
tio. For β_o real and negative the preamplifier phase
ift reduction due to negative feedback is given by

$$\sin\theta = \frac{1}{|1 - \mu_o\, \beta_o|} \sin\theta_o \qquad (13)$$

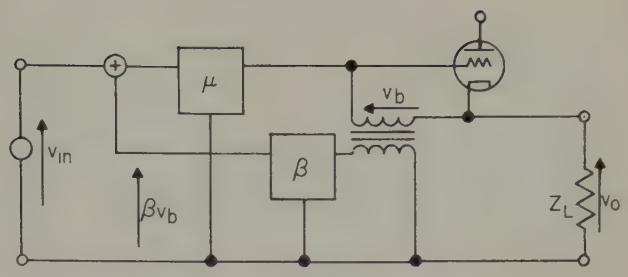


Fig. 4—The voltage analog of base current feedback applied to a cathode follower final stage.

where θ is the phase shift of μ and θ_o is the phase shift of μ_o. A convenient rule of thumb which follows from equations (12) and (13) is that for $\theta_o = 90°$ and θ small, the amount of improvement due to base current feedback is equal to the amount of preamplifier conventional feedback.

In summary of the foregoing, it is concluded that base current feedback provides a means of realizing considerable performance improvements in power amplifiers using a grounded base transistor final stage, while avoiding the loss of gain and stability problems associated with conventional negative feedback. However, base current feedback corrects only those amplifier imperfections due to final stage current transfer distortion and, in doing so, imposes precise transmission requirements on the preamplifier.

A convenient practical realization of base current feedback is shown in *Fig. 3*. The voltage drop across resistor R_b is applied to the preamplifier input in series with the signal input voltage. In this case the preamplifier transmission should be expressed as a transconductance G_t (output current divided by input voltage) and the base current feedback ratio

$$\mu\beta = G_t\, R_b$$

The feedback is conveniently controlled by varying R_b.

Two such amplifiers have been built and tested in the laboratory. The first of these was intended only to obtain experimental verification of the foregoing theory, and used a vacuum tube preamplifier. Measurements were taken of gain, distortion, and output impedance versus R_b. In each case the measurements agreed well with the theoretical predictions. Distortion improvements as great as 40 *db* were obtained. The second amplifier was a breadboard design for a specific wideband application and used a fully transistorized preamplifier driving a 952 final stage. In this case a distortion improvement of at least 15 *db* was maintained over a frequency range from 40 to 270 *kc/s*.

Figure 4 shows the voltage analog of base current feedback as applied to a cathode follower final stage. In this case the difference between final stage input and output voltages is the grid cathode voltage which is picked off via a transformer and fed back to the preamplifier input. The analysis is dual to that pre-

viously given and leads to similar results. The voltage transfer distortion of the cathode follower is reduced or eliminated while the amplifier output impedance is reduced by the feedback, becoming zero for the optimum adjustment.[4] Presumably a similar arrangement would be applicable to emitter follower output stages. This circuit has not been investigated experimentally.

Part II: THE FEEDBACK COMPOUND TRANSISTOR (Common Base)

A major disadvantage of base current feedback is the precise transmission requirements imposed on the preamplifier. This disadvantage can be circumvented to a considerable extent by feeding the base current directly back to the emitter via a second grounded base transistor as shown in *Fig. 5a*. Biasing details are not shown in the figure. In this case the feedback network is active and a different viewpoint is adopted in the analysis. The arrangement of *Fig. 5a* is viewed as a new semiconductor amplifying device, called a "feedback compound transistor," having emitter, base, and collector terminals as indicated. The more familiar Darlington compound connection (a feed-forward configuration) is shown in *Fig. 5b*. Both connections yield a compound *alpha* which is very close to unity. However, in the Darlington compound the collector-base capacity of the second transistor shunts the high impedance load terminals whereas in the feedback compound this capacity shunts the low impedance input terminals. Inasmuch as this capacity is a function of the instantaneous collector-base voltage it contributes directly to output distortion.

If each transistor of *Fig. 5a* is approximated by an equivalent circuit of the form shown in *Fig. 6* the short circuit current gain and open circuit output impedance of the feedback compound connection can be calculated directly. The results are

$$\alpha_c = \frac{\alpha_1}{1 - \alpha_2 (1 - \alpha_1)}$$

$$Z_{oc} = Z_{o1} \frac{1 - \alpha_2 (1 - \alpha_1)}{1 - \alpha_2}$$

where subscripts 1, 2, and c refer, respectively, to the power transistor, the feedback transistor, and the equivalent compound transistor. Additionally, the current gain to a load impedance Z_L can be expressed in the form

$$\alpha_{Lc} = \frac{\alpha_c}{1 + \frac{Z_L}{Z_{oc}}} = \frac{\alpha_{L1}}{1 - \alpha_2 (1 - \alpha_{L1})} \qquad (14)$$

where

$$\alpha_{L1} = \frac{\alpha_1}{1 + \frac{Z_L}{Z_{o1}}}$$

These equations are identical to equations (9), (10) and (7) with the substitution of α_2 for $\mu\beta$. The feedback transistor should therefore be chosen to have short circuit current gain close to unity and with small phase shift up to high frequencies. For α_2 near unity the values of α_c and α_{Lc} are almost exactly unity and almost independent of α_1 and α_{L1}.

Because the feedback compound transistor utilizes an active feedback path, an exact distortion analysis is difficult. However, an appreciation of the distortion improvement can be gained by considering the sensitivity of the current gain to changes in the controlling parameters. Thus by differentiating equation (14) we obtain

$$\frac{d\alpha_{Lc}}{\alpha_{Lc}} \Big/ \frac{d\alpha_{L1}}{\alpha_{L1}} = (1 - \alpha_2) \frac{\alpha_{Lc}}{\alpha_{L1}}$$

$$\frac{d\alpha_{Lc}}{\alpha_{Lc}} \Big/ \frac{d\alpha_2}{\alpha_2} = (1 - \alpha_{L1})\, \alpha_2 \frac{\alpha_{Lc}}{\alpha_{L1}}$$

It is worthwhile considering a numerical example. For $\alpha_{L1} = 0.8$ and $\alpha_2 = 0.98$ the value of α_{Lc} is 0.995 (a 25% increase over α_{L1}). A one percent change in α_1 changes α_{Lc} by only 0.025 percent while a one percent change in α_2 changes α_{Lc} by 0.25 percent. Variations in α_{L1} are reduced by 40 times (32 *db*) while variations in α_2 are reduced by 4 times (12 *db*). Thus distortion contributed by the power transistor is greatly reduced, while distortion contributed by the feedback transistor is appreciably reduced in the output. Because of this latter reduction, and because the feedback current is generally small, a properly biased feedback transistor contributes very little to output distortion.

The compounding of a power transistor increases the input impedance somewhat but does not correct for its nonlinearity. Consequently, the compound stage must be driven from a high impedance source if low output distortion is required. In the case of a single power transistor the effectiveness of source impedance (i.e. series emitter impedance) in reducing output distortion is not easily predicted. However, in the case of a compounded stage, the distortion reduction due to emitter impedance connected as in *Fig. 7a* is readily predicted when the compounding is effective. *Fig. 7b* shows an amplifying element with load impedance Z_L and input impedance Z_{in} (assumed nonlinear) driven from a voltage source v_s in series with an impedance Z. For this system

$$\frac{v_o}{v_i} = V_o = I_o \frac{Z_L}{Z_{in}} \qquad (15$$

where V_o and I_o are, respectively, the voltage gain and

[4] If required, the amplifier output impedance can be matched to the load impedance by applying 6 db of conventional negative feedback derived from the output current.

urrent gain of the amplifying element alone. The utput voltage and source voltage are related by

$$\frac{v_o}{v_s} = V = I_o \frac{Z_L}{Z + Z_{in}} \tag{16}$$

olving equation (15) for Z_{in} and substituting into quation (16) yields

$$V = \frac{V_o}{1 + \left(\frac{Z}{I_o Z_L}\right) V_o} \tag{17}$$

his equation is identical to the classical negative eedback formula except that the feedback ratio

$$\beta = \frac{Z}{I_o Z_L}$$

epends upon the current gain of the amplifying ele- ient.

It follows, then, that if β is truly constant the feed- ack is linear, and the per unit output distortion (at onstant output voltage) is reduced by the presence f Z in the same proportion that the voltage gain from ource to load is reduced by the presence of Z. On the ther hand, if β is not a constant the feedback is non- near, and the distortion reduction is not predictable. n the case of a single power transistor, the current ain ($I_o = \alpha_{L1}$) varies with instantaneous current am- litude and the feedback is nonlinear. The addition f series emitter impedance to such a stage yields the xpected voltage gain reduction but frequently there no corresponding distortion reduction. In the case f a properly compounded stage, however, the current ain ($I_o = \alpha_{Lc}$) remains very nearly constant and inde- endent of variations in α_{L1} and the feedback is essen- ally linear. Therefore, addition of series emitter im- edance to a compound stage reduces both voltage ain and distortion in the expected one for one rela- onship predicted by classical feedback theory. Con- equently, the compounding process may be viewed s an intermediate step by which the instantaneous urrent gain of the power transistor is stabilized in rder that subsequent emitter degeneration should ield the expected distortion reduction due to linear egative feedback. Since the feedback is current de- ved the output impedance is increased by the emit- r degeneration, approaching Z_{oc} as an upper limit. he input impedance seen by the driving source is ssentially equal to the emitter impedance Z.

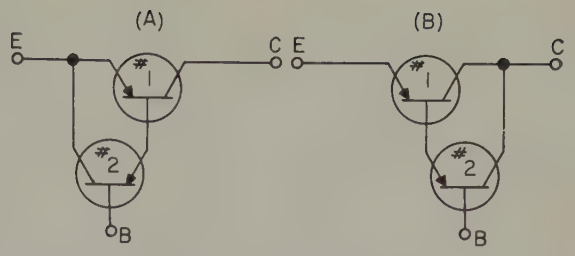


Fig. 5—(a) Feedback compound transistor. (b) Darlington compound transistor.

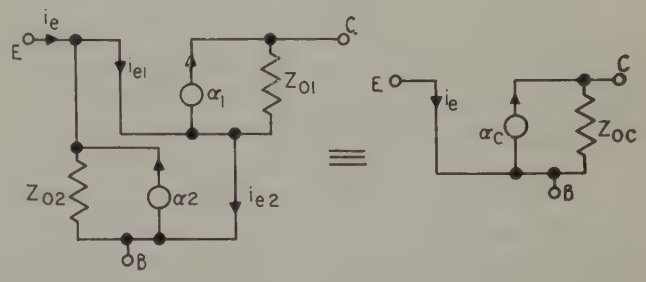


Fig. 6—Equivalent circuit of feedback compound transistor.

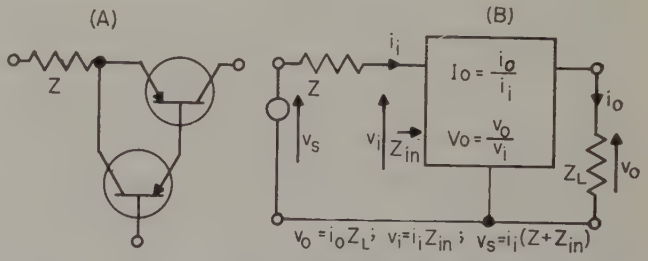


Fig. 7—(a) Application of emitter impedance to feedback compound transistor. (b) Source impedance applied to an amplifying element.

Part III: COMMON EMITTER PERMUTATION OF THE COMPOUND

Although the feedback compound transistor repre- ents a considerable improvement over a single rounded base transistor, both stages have the disad- antage that the input impedance is low and the river stage is required to supply a signal input cur- ent equal to the desired load current. In the case of a ngle power transistor this disadvantage is circum- vented by permuting the terminals into the grounded emitter configuration. Likewise, the feedback com- pound connection can be permuted to an equivalent grounded emitter configuration. When this permuta- tion is applied to the circuit of *Fig. 5a* the result is simply a cascade connection of a grounded collector stage (transistor #2) driving a grounded emitter power transistor. Although this result appears trivial at first sight, there is a most significant difference in the compound viewpoint when emitter degeneration is considered.

Conventionally, emitter degeneration is applied to such a cascade connection as in *Fig. 8a*. However, if the cascade connection is viewed as a single com- pound transistor the emitter degeneration is properly applied as in *Fig. 8b*. Although the two circuits differ only in the connection of one lead, the difference in performance is equivalent to that already demon-

strated for the grounded base configuration. This can be shown as follows.

In *Fig. 8b*, the feedback transistor, operating under near short circuit conditions, returns $\alpha_2 i_b$ to the emitter of the power transistor so that the current flowing through the emitter impedance is

$$i_e - \alpha_2 (i_e - i_o) = \frac{1}{\alpha_{Lc}} i_o \qquad (18)$$

where $\alpha_{Lc} = \dfrac{\alpha_{L1}}{1 - \alpha_2 (1 - \alpha_{L1})}$ and $\alpha_{L1} = \dfrac{i_o}{i_e}$

The voltage drop across the emitter impedance is

$$v_e = - Z \frac{i_o}{\alpha_{Lc}} = - \frac{Z}{\alpha_{Lc} Z_L} v_o \qquad (19)$$

The total input voltage is

$$v_i = v_d + v_e$$

where v_d is the small voltage drop across the two base-emitter junctions. Substituting for v_e and dividing by v_o yields

$$\frac{1}{V} = \frac{1}{V_o} - \frac{Z}{\alpha_{Lc} Z_L}$$

where $V = \dfrac{v_o}{v_i}$ is the voltage gain

and $V_o = \dfrac{v_o}{v_d}$ is the voltage gain when $Z = 0$.

This last equation can be written

$$V = \frac{V_o}{1 - \left(\dfrac{Z}{\alpha_{Lc} Z_L}\right) V_o} \qquad (20)$$

which is in the form of the classical feedback equation. For a single power transistor or for the circuit of *Fig. 8a* a similar result is obtained except that α_{Lc} is replaced by α_{L1}.

Thus the discussion following equation (17) applies equally well here, with the conclusion that the compounded circuit of *Fig. 8b* yields the distortion reduction predicted by linear feedback theory while the conventional circuit of *Fig. 8a* does not. The sign difference between equations (17) and (20) results from the phase inversion in a grounded emitter configuration. In equation (17), V and V_o are positive; in equation (20) V and V_o are negative. Because the feedback is current derived, the output impedance is increased by the emitter degeneration. For moderate to large amounts of feedback

$$V \cong - \frac{Z_L}{Z}$$

and the output impedance is almost infinite.

In the compounded circuit of *Fig. 8b* the input voltage is almost equal to the feedback voltage while the input current is $(1 - \alpha_{Lc})$ times the current through the feedback impedance. Consequently the input impedance of the compounded stage is very nearly

$$Z_{in} = \frac{Z}{1 - \alpha_{Lc}}$$

Typically this impedance is very much larger than the shunt impedance of the base biasing network and may be neglected in computing the load on the driving stage. This may not be the case for the conventional circuit of *Fig. 8a* where the base to collector capacity of the grounded collector stage is directly across the input terminals. If the compound circuit of *Fig. 8b* is replaced by the Darlington connection, this capacity is connected directly between input and output terminals and the effective input capacity is this capacity multiplied by the stage voltage gain. Because this capacity varies with instantaneous voltage, it contributes to nonlinear distortion as well as degrading the frequency response of the driver.

Practical circuit realizations of the compounded transistor connection in common emitter configuration are shown in *Fig. 9*, where the two transistors are of like or unlike conductivity types as illustrated. Resistors R_1 and R_2 form a voltage divider stiff enough to set the transistor bases at the desired *d-c* voltage. Separate biasing of the power transistor base is not required because of the direct coupling. Emitter and collector biases for the feedback transistor are supplied through R_3 and R_4, and C is a *d-c* blocking condenser which should have negligible impedance to signal frequencies. Where like conductivity types are used R_3 might be omitted, but is preferably retained for reasons of *d-c* stabilization. Where unlike conductivity types are used R_4 and C may be omitted and the collector bias for the feedback transistor obtained from a Zener diode connected as in *Fig. 9c*. The total degenerative emitter impedance is the parallel combination of R_4 and R_5. The emitter bias current of the power transistor may be sufficiently stabilized by R_5. If not, an adequately bypassed resistor can be connected in series with R_5.

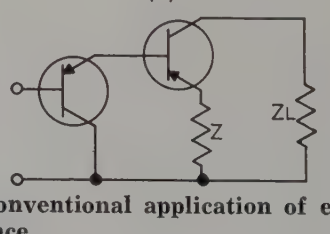


Fig. 8—(a) Conventional application of emitter impedance.

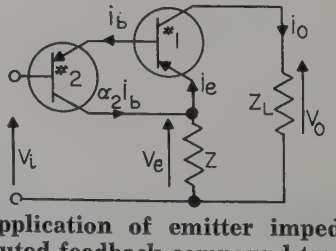


Fig. 8—(b) Application of emitter impedance to permuted feedback compound transistor.

Resistor R_3 provides a path whereby a small portion of the signal base current of the power transistor is lost from the feedback path. Fortunately, this current loss is much less serious than might be expected. It may be accounted for analytically by observing that the signal voltage across R_3 is very nearly equal to that across the emitter impedance, so that equation (18) should be corrected to read

$$i_e - \alpha_2\left(i_b - \frac{v_e}{R_3}\right) = \frac{1}{\alpha_{Lc}} i_o + \alpha_2 \frac{v_e}{R_3}$$

Then equation (19) becomes

$$v_e = -\frac{Z}{\alpha_{Lc} Z_L} v_o - \alpha_2 \frac{Z}{R_3} v_e$$

and

$$v_e = -\frac{Z}{\alpha_{Lc} Z_L\left(1 + \alpha_2 \frac{Z}{R_3}\right)} v_o$$

Thus the effect of R_3 is to reduce the feedback ratio by the factor $(1 + \alpha_2 Z/R_3)$ which is nearly unity for representative values of Z and R_3.

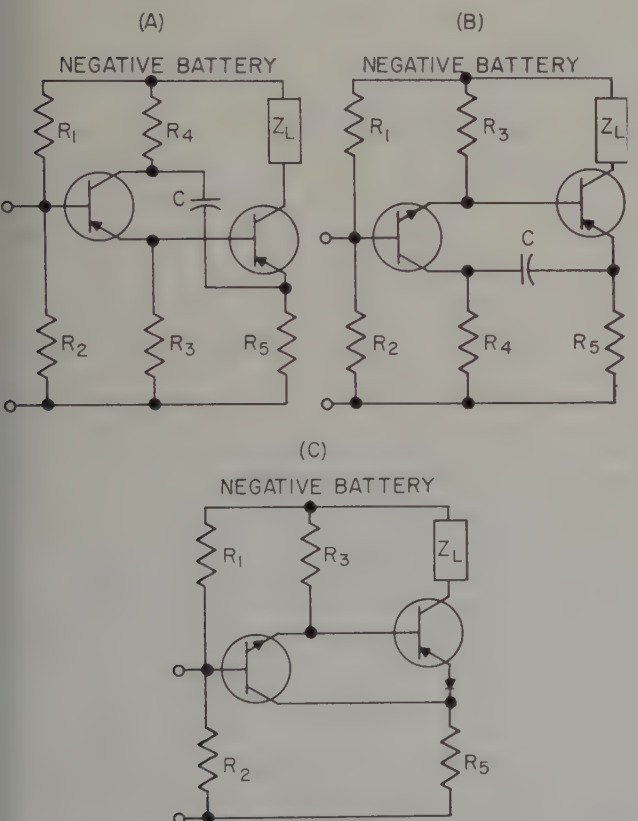


Fig. 9—Practical circuit realizations of common emitter feedback compound transistor.

The choice of the power transistor will depend on the amplifier output requirements. In choosing the feedback transistor, one should bear in mind that the base current of the power transistor becomes rather large as α_{L1} departs from its low frequency value (for $\alpha_{L1} = 0.71/\underline{45}°$, the base current is equal to the output current) and that the base current contains large percentages of the distortion products of the signal frequency. For effective compounding α_2 is required to be constant and near unity with low phase shift at the anticipated base current amplitudes and frequencies. When these requirements cannot be met in a single transistor, double compounding may be employed. Two possibilities are illustrated in *Fig. 10*. In the first case, transistor #3 is used as a feedback transistor to compound the already compounded stage formed by transistors #1 and #2. In the second case, transistors #2 and #3 form a compound stage which is used as the feedback transistor for transistor #1. Alternatively, the first case may also be viewed as transistors #2 and #3 connected in Darlington compound, and used as the feedback transistor for transistor #1. In any case the two arrangements illustrated have proved to be equally effective.

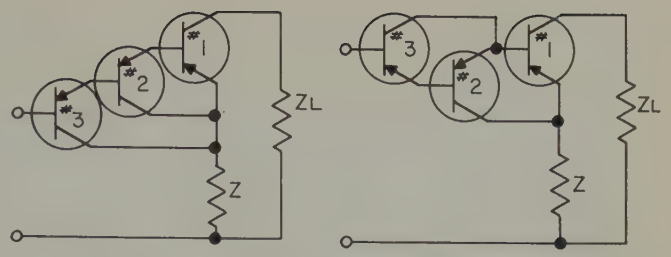


Fig. 10—Two choices for double compounding in common emitter configuration.

The effectiveness of compounding in reducing power transistor distortion has been demonstrated in the laboratory by means of the following experiment. A power transistor is connected in common emitter configuration, and voltage gain and output distortion are observed at a reference output level. Next, a degenerative impedance is connected in the emitter lead, the output adjusted to the reference level, and the decrease in gain (ΔG) and output distortion (ΔD_z) are recorded. This clearly demonstrates that the reduction in output distortion is much less than the reduction in gain. Finally a feedback transistor is added to the circuit as in *Fig. 9a* or *9b* without altering the emitter impedance. This addition does not change the voltage gain, but the output distortion is reduced considerably. The additional decrease in output distortion due to compounding (ΔD_c) is recorded and the total decrease in distortion due to both compounding and emitter degeneration (ΔD) is computed. Table I gives some typical experimental results. The first six entries are for medium power transistors compounded with small signal transistors. The last two entries are for a high power transistor compounded with a medium power transistor and doubly compounded with a small signal transistor.

Part IV: CONCLUSION

This article has described two different realizations of the base current feedback principle. The first of

TABLE I

T1	f kc/s	z ohms	ΔG *db*	ΔD_z *db*	T2	ΔD_c *db*	T3	ΔD_{cc} *db*	ΔD *db*
2N340	60	80	21	7	2N247	16			23
2N340	90	80	21	5	2N247	21			26
952	60	80	24	5	2N247	20			25
952	90	80	23	5	2N247	21			26
MN13C	60	80	23	−6	GT762	24			18
MN13C	90	80	21	−3	GT762	21			18
2N301A	15	30	22	1	MN13C	13	GT762	11	25
2N301A	24	30	21	0	MN13C	8	GT762	10	18

T1: Power Transistor
f: Signal Frequency
z: Emitter Impedance
ΔG: Reduction in voltage gain due to emitter impedance
ΔD_z: Reduction in output distortion due to emitter impedance
T2: Feedback Transistor
ΔD_c: Additional reduction in output distortion due to compounding
T3: Second Feedback Transistor
ΔD_{cc}: Additional reduction in output distortion due to double compounding
ΔD: Total reduction in output distortion

Transistor Identification

952 —Texas Instrument Co.
MN13C —Motorola
GT762 —General Transistor Corp.

Table I—Experimental results showing the effectiveness of compounding in reducing power transistor distortion.

these involves feedback via the preamplifier and the distortion improvement depends upon the preamplifier transmission characteristic, which can be closely controlled by conventional negative feedback. The second realization involves a feedback transistor and the combined circuit is called a feedback compound transistor. The distortion improvement depends on the short circuit current gain (*alpha*) of the feedback transistor. The feedback compound transistor has been treated in both common base and common emitter configurations with degenerative emitter impedance in each case. The voltage gain is the same for each but the common emitter configuration has much greater input impedance and is preferred for this reason. It has been used, with excellent results, both as a single stage amplifier and as the final stage in multistage amplifiers where distortion requirements were severe.

The author has been associated in his work on base current feedback and compound transistors with Mr. James Stewart, Mr. Torvald Eskedal, and Dr. Macrobio Lim. Mr. Eskedal did much of the experimental work. Mr. Stewart has recently published a paper treating the common emitter configuration of the feedback compound connection in greater detail than has been given here. His paper contains additional experimental data on distortion reduction and also gives the equivalent *y*-parameters for the compound connection in terms of the *y*-parameters of the individual transistors. Dr. Lim has used these parameters to develop simple design equations for single stage compound amplifiers with equal input and output impedances. These equations, together with performance data on two such designs, are included in Mr. Stewart's paper.

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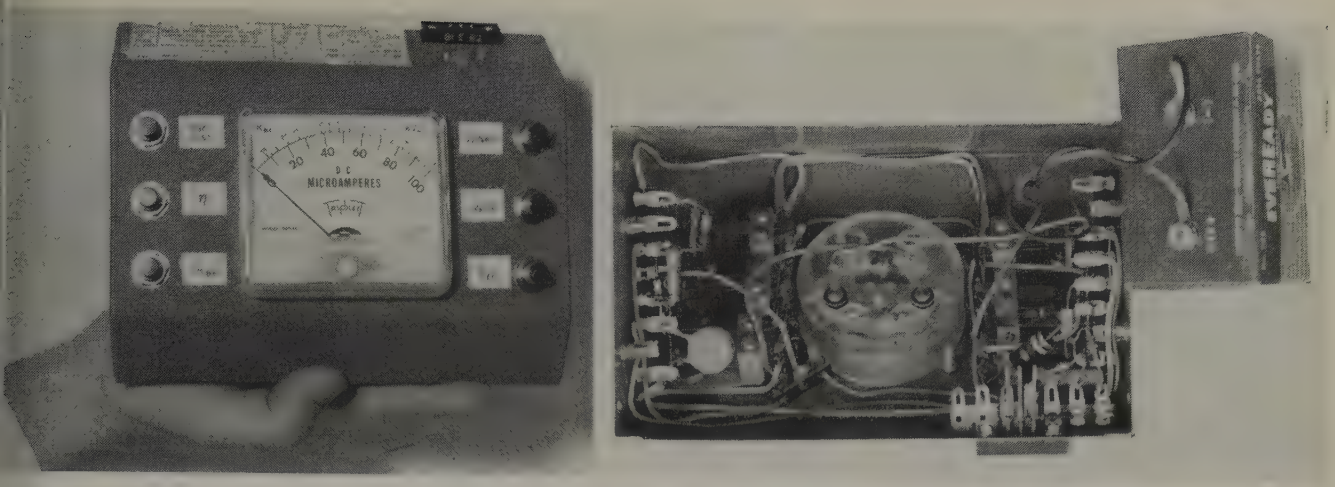


Fig. 8—Front and rear view of fabricated test set.

UNIJUNCTION TRANSISTOR TEST SET

T. P. SYLVAN*

A test set is described which measures six parameters of the unijunction transistor. The test set is battery operated and completely self-contained. Maximum convenience of operation is achieved by the use of an individual push button switch for each measurement.

THE UNIJUNCTION transistor has electrical characteristics which are significantly different from those of the conventional junction transistor. It is therefore necessary to have special test equipment for measuring the important parameters of this device.

A test set is described which can be used to measure six parameters of the unijunction transistor. These parameters are indicated in Chart I.

The test set is battery-operated and completely self-contained. Use of a Zener diode for voltage stabilization eliminates the need for recalibration and zero setting. Maximum convenience of operation is achieved by the use of an individual push-button switch for each measurement. (See *Figs. 7 and 8*)

Test #1—Oscillator Test (Peak to Peak Emitter Voltage)—*Fig. 1*

The oscillator test is the fundamental test for determining whether or not a particular unijunction transistor is a usable unit. A unijunction transistor may be capable of operating in a relaxation oscillator circuit even though many of its basic parameters may have values which are greatly different from the normal values.

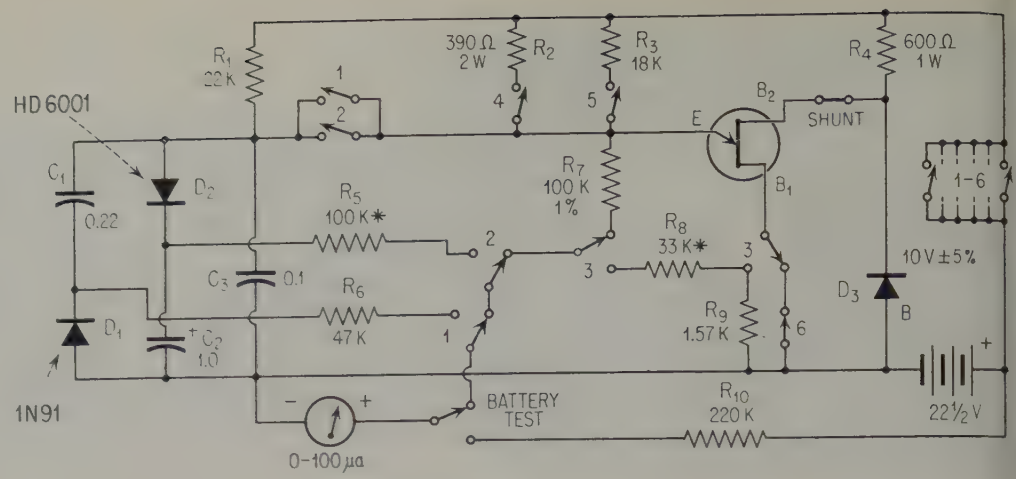
TEST	SYMBOL	PARAMETER	RANGE	CONDITIONS
1	Osc.	Peak to peak emitter voltage	0-10 V	$V_{BB} = 10\ V$, $C = 0.1\ \mu f$
2	η	Intrinsic Stand-off Ratio	0-1.0	$V_{BB} = 10\ V$
3	R_{BB}	Interbase Resistance	$3K$-∞	$P < 15\ mw$
4	$V_{E(sat)}$	Emitter Saturation Voltage	0-10 V	$V_{BB} = 10\ V$, $I_E = 50\ ma$
5	$V_{E(1)}$	Emitter Voltage at 1 ma	0-10 V	$V_{BB} = 10\ V$, $I_E = 1\ ma$
6	I_{EO}	Emitter Leakage Current	0-100 μa	$V_{EB2} \geq 10\ V$

The circuit shown is a simple relaxation oscillator of about 1 *kc*. The meter reads the approximate peak to peak emitter voltage. The exact value of the peak to peak emitter voltage can be easily calculated for any value of interbase voltage (V_{BB}) by the use of the equation:

$$V_E \text{ (peak to peak)} \cong 0.7 + \eta V_{BB} - \tfrac{1}{2}\ V_{E(sat)}$$

*Semiconductor Products Department, General Electric Company, Syracuse, New York.

NOTE:
(1) All switches shown in the inactive position.
(2) All components ±5% except as indicated.
(3) * Denotes approximate values, must be calibrated.



Parts List

Switches **(Push-Button Types)**

Test	1	3PDT	Switchcraft #1009
	2	3PDT	" "
	3	3PDT	" "
	4	DPST (normally open)	" #1004
	5	DPST (normally open)	" "
	6	DPDT	" #1006
Battery		SPDT	" #1003

Meter

Triplett #327-PL
0-100 microamperes, 3½" rectangular

Panel

ICA Metal Products #3906 (cover #4156)
Sloping Front, 4½" x 7 5/16" x 4¼"

Diodes

D1 G.E. 1N91 Germanium Junction Diode
D2 Hughes HD6001 Silicon Junction Diode
D3 Transitron SV-810 Silicon Regulator Diode, 10 volts ±5%, 750 *mw*

Battery

Eveready Type 763 or Burgess 4156

Fig. 7—Complete Circuit Schematic—Unijunction Transistor Test Set.

Test #2—Intrinsic Stand-off Ratio (η)—Fig. 2

The intrinsic stand-off ratio, η, is the most important parameter of the unijunction transistor. It determines the value of the peak emitter voltage, V_p, in terms of the interbase bias voltage, V_{BB}. The equation expressing this relationship is:

$$V_p = \eta V_{BB} + V_D$$
$$V_D \cong 0.7 \text{ volt at } 25°C$$
$$V_D \cong 0.3 \text{ volt at } 125°C$$

It is found that η is very independent of V_{BB} and temperature. The only significant variation with temperature is that of V_D which decreases with increasing temperature.

The circuit shown is a simple relaxation oscillator with a peak voltage detector. The forward drop of the silicon diode used in the peak voltage detector effectively subtracts about 0.7 volts (V_D) from the peak voltage so that the meter indicates η directly. The resistor R_5 is adjusted so that the meter reads full scale when the upper terminal of R_5 is connected to the upper terminal of the zener diode.

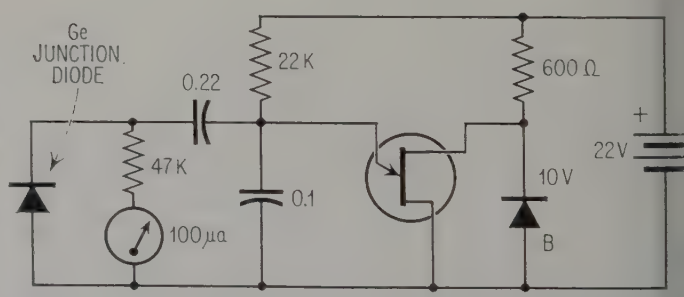


Fig. 1—Test #1; Oscillator Test (Peak to Peak Emitter Voltage).

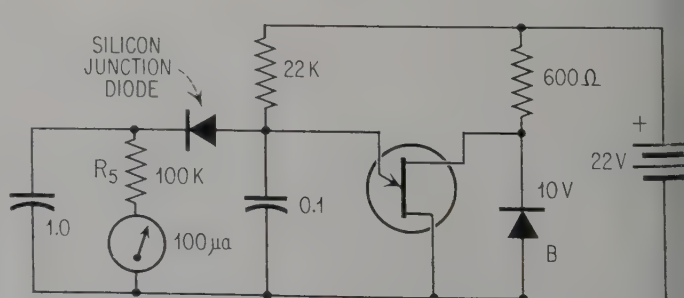


Fig. 2—Test #2; Intrinsic Stand-off Ratio (η).

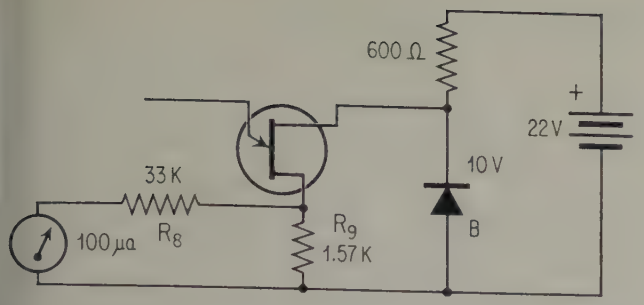


Fig. 3—Test #3; Interbase Resistance (R_{BB}).

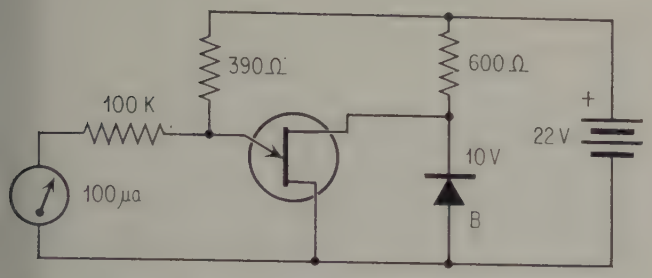


Fig. 4—Test #4; Emitter Saturation Voltage V_E (sat).

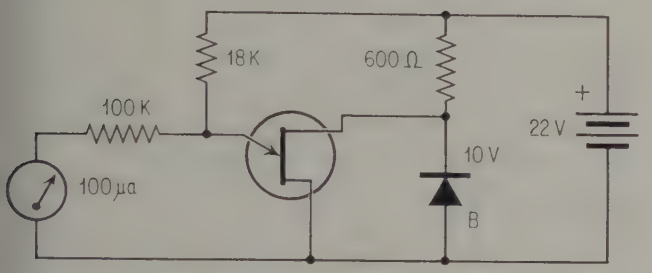


Fig. 5—Test #5; Emitter Voltage at I_E = 1 ma.

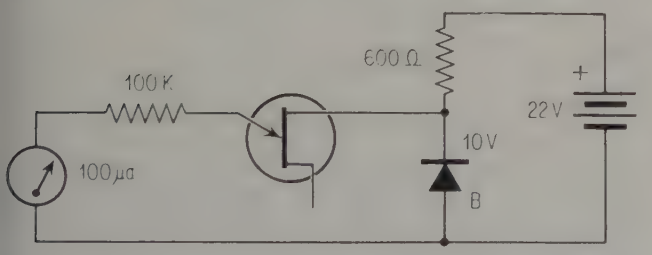


Fig. 6—Test #6; Emitter Leakage Current (I_{EO}).

Test #3—Interbase Resistance (R_{BB})—Fig. 3

The interbase resistance, R_{BB}, has a temperature coefficient of approximately +0.8%/°C. It is normally measured and specified at lower power dissipations with a bar temperature of 25°C. The circuit shown is a conventional ohmmeter circuit designed to read approximately 3 kilohms full scale. This permits an expanded scale for the normal range of R_{BB} (4.7K-9.1K). The maximum power dissipation in the unijunction transistor will be about 15 milliwatts corresponding to a temperature rise of 8°C or a change of R_{BB} of 6%. This effect can be taken into account in constructing the resistance scale for the meter. The resistance *R8* and *R9* are selected to give the correct meter calibration.

Test #4—Emitter Saturation Voltage V_E (sat)—Fig. 4

The emitter saturation voltage, $V_{E(sat)}$, provides an indication of the switching abilities of the unijunction transistor in the emitter to base-one circuit. This voltage is normally specified at an interbase voltage of 10 volts and an emitter current of 50 milliamperes. The upper production test limit on this parameter is 5 volts.

This measurement also provides an indication of the total power dissipation capabilities of a particular unit. Some units can dissipate as much as 450 *mw* in circuits such as this where precautions are taken to prevent thermal runaway in the base 2 region. If precautions are not taken to limit the base 2 dissipation, then the 250 *mw* rating must be used in circuit design.

Test #5—Emitter Voltage at I_E = 1 *ma*—Fig. 5

This test along with the test for η provides an indication of the slope of the emitter characteristic in the negative resistance region near the peak point. Tests number 2, 4, 5 and 6 provide four points on the emitter characteristic curve.

Test #6—Emitter Leakage Current (I_{EO})—Fig. 6

The test for emitter leakage current is made with a reverse bias of 10 volts across the emitter junction as shown. This voltage is considerably lower than the 60 volts used as a production test and specified for the regular types of unijunction transistor. The specified maximum value of I_{EO} at 25°C and 60 volts is 1 μa so a good unit in this test should give a deflection on the 100 μa meter which is barely detectable.

This test is primarily useful in detecting units which have been damaged by exceeding the maximum ratings. Such damage usually shows up as an increase in I_{EO} before any of the other parameters are noticeably affected.

Other Tests

Several other tests are made possible by including a shunt in the base-two circuit. If the shunt is removed (base-2 open circuited) and the button for test 4 is pushed, the meter will read the emitter to base-one diode voltage, V_{EB1} (diode). From this, the base-2 saturation voltage may be calculated from the equation:

$$V_{B2}\ (\text{sat}) \cong V_{EB1}\,(\text{diode}) - 0.8$$

Similarly if the shunt is replaced by a milliammeter and the button for test 4 is pushed, the external meter will read the base-two modulation current I_{B2} (mod). This current provides an indication of the ability of a particular unit to switch heavy loads in the base-two circuit. The nominal value for I_{B2} (mod) is 12 milliamperes with a range of 6.8 to 22 milliamperes.

Transistor Bilateral Switches

PART 2

WM. M. COOK* and PIER L. BARGELLINI‡

In many electronic equipments large numbers of electro-mechanical relays are used for low level *a-c* and *d-c* signal switching purposes. Transistors are being widely used to replace relays in *d-c* switching and the techniques in this area are reasonably well-known. The application of transistors as *a-c* switching elements has received much less attention. The purpose of this article is to present techniques for replacing *a-c* signal relays with transistor bilateral switches. Part I, in the July/August issue discussed the theoretical aspects of the problem. This concluding installment deals with applications.

In Part I of this article (Semiconductor Products July/August 1958), the analogy between the characteristics of a realizable switch and those of a symmetrical transistor were discussed; the bilateral switch mode of operation of transistors was described and transistor equivalent circuits for bilateral operation were presented and used to analyze the effects of transistor and circuit parameters on the performance of basic shunt and series switching circuits. Certain difficulties encountered in the use of transistors as bilateral switches were pointed out. These include:

1. The forward base current produces a *dc* current and voltage component at both the input and output of shunt and series switches. This difficulty is considerably more severe in series switching.
2. Even though the shunt switch is more satisfactory from the *dc* standpoint it is applicable only to relatively high impedance circuits.
3. The series switch also suffers from loading of the signal circuit by the control circuit and modulation of the base current by the signal when the switch is *on*.
4. To obtain good high frequency isolation a low base impedance is required in the series switch when it is *off*. This, however, is in opposition to the requirements for minimizing the above mentioned loading effects.

In this installment, circuit techniques for the alleviation of the above difficulties will be discussed. Practical circuits which have been built and tested will be described and performance data presented. Although the series switch presents greater difficulties it can be considered generally more useful. Therefore circuit techniques for series switching will be emphasized. Many such techniques are applicable to shunt switches also.

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BASE CONTROL FOR SERIES SWITCHES

To achieve adequate *off* isolation and low *on* attenuation in high frequency series switches, the base impedance must assume low and high values respectively. The base impedance and bias requirements can be satisfied through the appropriate use of bi valued impedance elements. The low impedance state of the non-linear elements must be effective when the series switch is *off* in order to obtain low feed thru (high isolation). The high impedance state must be effective when the series switch is *off* in order to obtain low attenuation. The base control techniques indicated in *Fig. 9* fulfill these requirements.

Diode Controlled Series Switch

Referring to the diode controlled series switch of *Fig. 9:* the application of a positive voltage $V_{BR} > + \hat{V}_{IN}$ at the control input terminal will forward bias the diode and reverse bias the switch transistor. The total base circuit impedance is then:

$$Z'_B = r_b + r_d + r_v$$

Where: r_b is the intrinsic base resistance of the transistor.
r_d is the forward *ac* resistance of the diode
r_v is the *ac* impedance of the V_{BR} source

When the switch transistor is to be *on*, the diode must be reverse biased for all values of the input signal to avoid distortion and loading in the signal circuit. This requires that $V_{BR} < -\hat{V}_{IN}$. The base impedance under this condition is:

$$Z'_B = r_b + Z_d \,||\, R_b$$

Where: Z_d is the *off ac* impedance of the diode given by

$$Z_d = \frac{1 + j\omega C_d r_{dL}}{r_{dL}}$$

C_d is the diode transition capacitance
r_{dL} is the diode leakage resistance.

The forward voltage, $-V_{BF}$, and the base resistance, R_B, can assume high values, the only require

ent is that sufficient base current be supplied. In cir-
its where *on* loading is an important factor,—V_{BF}
ay be as high as 300 volts. This allows R_B to be very
rge, hence presenting negligible additional loading
the signal circuit. Under these conditions:

$$Z'_B \approx Z_d \text{ at high frequencies}$$
$$Z'_B \approx r_{dL} \,||\, R_B \text{ at low frequencies}$$

or $V_{BF} \gg \hat{V}_{IN}$ the power requirements of the switch
e directly proportional to V_{BF}, since the forward
ase current required is essentially constant.

ansistor Controlled Series Switch

Referring to the transistor controlled series switch
Fig. 9, the switch transistor is *on* when V_{BR} is ap-
ied at the control input terminal. With V_{BR} at both
s base and emitter, the control transistor is off and
rward base current is supplied to the switch tran-
stor through R_B and $-V_{BF}$. In actual practice the
ase-emitter junction of the control transistor should be
everse biased by at least a few tenths of a volt. This
especially true for high temperature operation.
hen the control input is taken to ground, the con-
ol transistor is biased to saturation by V_{BR} at its
nitter. The base of the switch transistor is then at
$_{BR}$ through the saturation resistance of the control
ansistor. It should be noted that a unipolar control
gnal is required for this circuit while a bipolar con-
ol signal is required for the diode controlled circuit.
The control transistor and a second additional tran-
stor can be cross coupled to form a control flip-flop
hich provides a latching switch action. This config-
ration is shown in *Fig. 10* for a single pole-double
row latching signal switch circuit. In the circuit
own, the output is either signal S_1 or S_2 depending
pon the state of the flip-flop. The circuit can also be
ranged to supply a single input signal to either one
two outputs. It should be noted that a transistor
ovides only single-pole single throw action. Single
le-multiple position switching requires a transistor
r each switch position. In the circuit of *Fig. 10*, the
gnal amplitude at the collectors of the control tran-
stors must be taken into account in the design of the
ntrol flip-flop. This technique has proven useful
hen the signal swing is small and when base loading
the signal circuit is not of major concern. For large
gnal amplitudes an external flip-flop can be used to
ive either series circuit of *Fig. 9*.

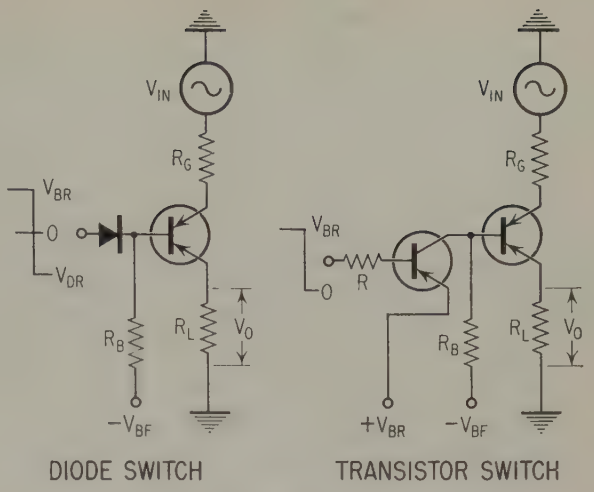

Fig. 9—Base switching in series switches.

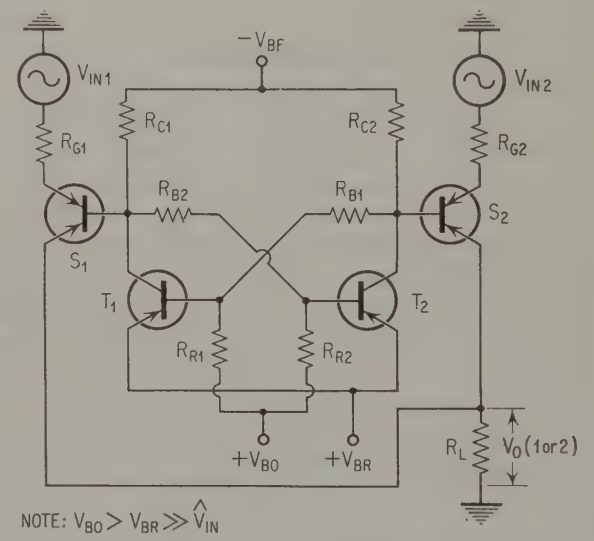

Fig. 10—Flip-Flop controlled single pole-double throw latching series switch.

EDUCTION OF DC COMPONENTS IN SERIES SWITCHES

In many applications, the introduction of *dc* com-
onents into the signal circuit by a control circuit is
ndesirable. Consequently, the base current of the
vitch transistor poses serious limitations on the use-
lness of transistors as switches. However, a number
techniques can be employed to greatly reduce the
fect of base current on the signal circuit. These tech-
ques depend upon the use of a compensating *dc* cur-
rent of the same magnitude but opposite polarity. This compensation current is injected into the signal circuit. Since the base current and the compensating current are nearly equal, but opposite in polarity, they tend to cancel. The effective *dc* voltage component across the output is then reduced to a few millivolts with reasonable circuit tolerances. There are several ways of obtaining this compensating current as indicated in the following circuits.

Complementary Series Switches

The circuits of *Fig. 11* utilize complementary, symmetrical transistors in parallel and series arrangements as series switches. Since the base currents of complementary transistors are of opposite polarity their effects in the signal circuit tend to cancel. In this application both transistors are driven *on* or *off* at the same time.

The parallel complementary circuit of *Fig. 11* has several unique features. If the transistors have the

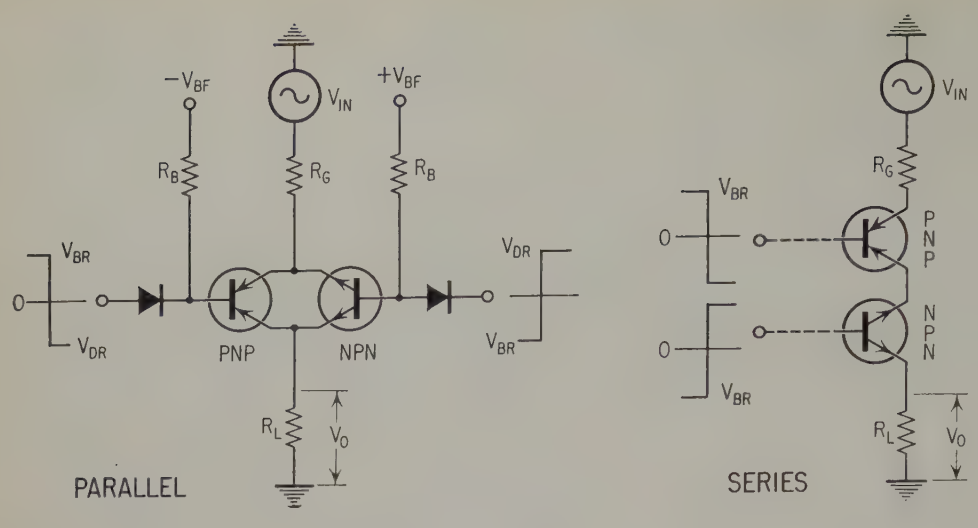

Fig. 11—Complimentary symmetrical series switches.

same cutoff currents and speed of response, then all control signal and transistor effects will cancel as far as the load and source are concerned. Even if the units are not identical, considerable reduction in control signal and transistor effects can be realized. This circuit also reduces the *on* resistance of the switch to approximately half the value for a single unit. Even more important is the compensation of the curvature in the effective *on* resistance characteristics. The signal tends to oppose the base current of the *p-n-p* unit while it is aiding the base current of the *n-p-n* unit and vice versa. This action will allow large signal current swings with good linearity. It should be pointed out that this parallel arrangement can also be used effectively in shunt switching where particularly low *dc* components, both *on* and *off*, are required.

The major disadvantage of the parallel complementary circuit is that the feed-thru paths of the two transistors are in parallel. Consequently, the feed-thru effects are higher in this circuit than in the single transistor circuit for given source and load impedances. Also the capacitance loading of the source and load is approximately twice that of the single transistor circuit.

The series complementary circuit of *Fig. 11* has better *off* characteristics than the parallel circuit, as to be expected. The feed-thru is lower and the capacitance loading is essentially the same as that of a single transistor switch. The *on* properties of the series arrangement are not as desirable as those of the parallel arrangement. The saturation resistance is higher and more non-linear than that of either the parallel or single unit switches. However, the base currents still tend to cancel. The condition of minimum *dc* components in the signal circuit is not when the two currents are equal. The base-to-base path of the base current is through the saturation resistance of two junctions in series in the signal path, developing a *dc* voltage component in the signal path. By making the base currents slightly unequal the *dc* voltage at the input or the output can be reduced to nearly zero. The two conditions will not be satisfied simultaneously.

Both complementary circuits require balanced drives. The diode base control circuit is shown for the parallel complementary arrangement. Either of the base control circuits shown in *Fig. 9* is applicable to either the parallel or series configuration.

Balanced Series Switches

Compensation of *dc* components in the source and load can also be obtained without making recourse to complementary symmetry circuits. Two circuits providing *dc* compensation which use transistors of the same conductivity are shown in *Fig. 12*. One of these employs two transistors in series as a single switch; the other provides multiple inputs and a single output or vice versa using a single switch transistor per switch.

Two Transistor Series Switch

In this circuit a current equal to the sum of the base currents required by the two transistors is supplied at the bases. A current of the same magnitude, but opposite polarity is supplied at the common point between the two transistors. If the characteristics of two transistors are identical, the currents will divide equally between the two units. Since the base currents flow in opposite directions in the signal paths, their effects cancel. Resistors must be placed either in the signal circuit or in the two bases to assure proper division of base currents when the two units are not identical. See *Fig. 12*.

To turn this switch *off*, the control transistor is allowed to saturate and $+V_{BR}$ is applied at the bases of the switch transistors. $+V_{BR}$ must be more positive than $+V_{BF}$ as well as $+V_{IN}$ to turn *off* the switch transistors. The addition of a diode between the center point of the circuit and a voltage V_{ER} such that $V_{BR} > V_{ER} > \hat{V}_{IN}$ will allow V_{BF} to be any large value consistent with the *on* loading requirements. This circuit provides excellent isolation properties since the two transistors are off and the diode between them is forward biased when V_{BR} is applied at the bases.

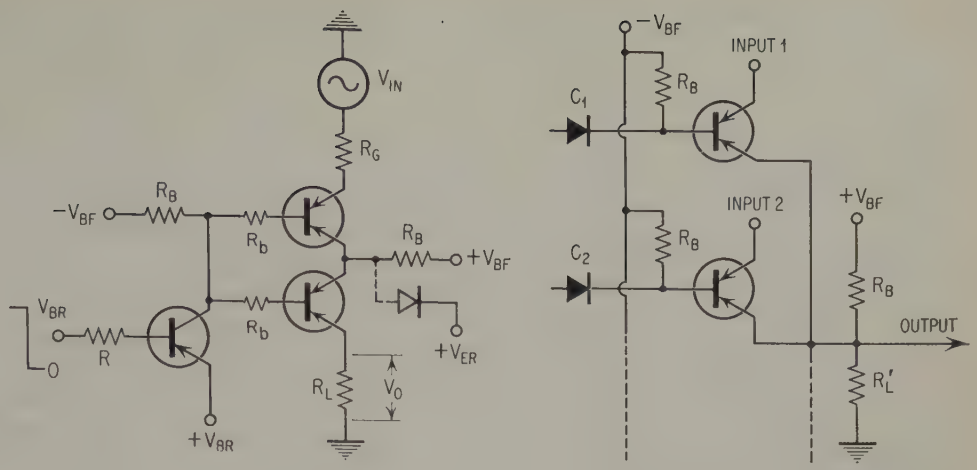

Fig. 12—Balanced series switches.

ase Current Compensation in Multiple Switch Circuits

In the multiple input circuit of *Fig. 12*, a current qual and of opposite polarity to the base current re-uired by any single switch is supplied at the common utput. To operate properly only one input signal can e connected to the output at a time. Furthermore, his condition must always be maintained. Conse-uently, a dummy input must be provided for the ase when all signal inputs are to be open. The value f the load resistance can be adjusted to give the roper termination taking into account the effect of $_B$ added at the output, i.e.,

$$\text{Termination } R = R_B \,||\, R'_L$$

TRANSFORMER COUPLED TRANSISTOR BILATERAL SWITCHES

The transistor switches which have been discussed o far are directly coupled to the control signal source. Consequently, they can be operated at any arbitrarily ow duty cycle and repetition rate. If a switch is re-uired that will open and close at a fairly constant uty cycle and repetition rate, transformer coupling f the control signal can be employed to reduce the *dc* omponents of the control signal in the load. Two cir-uits which use transformer coupling of the control gnal are shown in *Fig. 13*.

ransformer Coupled Floating ase Transistor Series Switch

In this circuit, the driving pulses are transformer oupled to the base of the switch transistor. The sec-ndary of the pulse transformer is connected through current limiting resistor R_B and a capacitor C_B be-veen the output (or input) point and the base ter-inal. A diode (or resistor) is placed across the sec-ndary of the transformer to prevent ringing. The alue of C_B is chosen so that the charge placed upon during the forward base pulse is sufficient to main-in the base reverse biased during the *off* period. The reverse base voltage V_{BR} connected to the base through R_{BR} serves two purposes:

1. To compensate for variations in the discharge time of C_B due to variations of reverse base current with temperature.
2. To maintain the transistor in the *off* condition if the control signal is interrupted.

It should be noted that C_B blocks the flow of *dc* current from V_{BR} to the load. However, a small current will flow in the load while C_B is charging to V_{BR}. The magnitude of this current is determined by the magnitude of V_{BR} $(R_{BR} + R_B + R_L)$ and the amount of the charge on C_B immediately after the forward pulse. When the base is driven negative by the forward pulse the major portion of the current flows around the transformer loop. The voltage drop across the saturated junction in the transformer loop will induce a very small *dc* current in the signal circuit.

Balanced Transformer Coupled Series Switch

By transformer coupling the two transistor switch of *Fig. 12* in the manner shown in *Fig. 13* further reductions in the *dc* components are possible. In this circuit, no bias is required for the bases since either the junction next to the source or the one next to the load is reverse biased depending on the polarity of the input signal.[1] However, considerable improvement in the *off* isolation is obtained using the techniques described above. The transformer coupled circuits will not in general give the degree of isolation obtainable with the direct coupled circuits. In the case of the single transistor transformer coupled circuit, only the junction next to the source provides isolation at high signal frequencies. In the two transistor circuit with the base biased, the junction next to the source is in series with the one next to the load so far as high frequency isolation effects are concerned.

EFFECTS OF THERMAL CURRENTS

In Part I of this article it was noted that the reverse

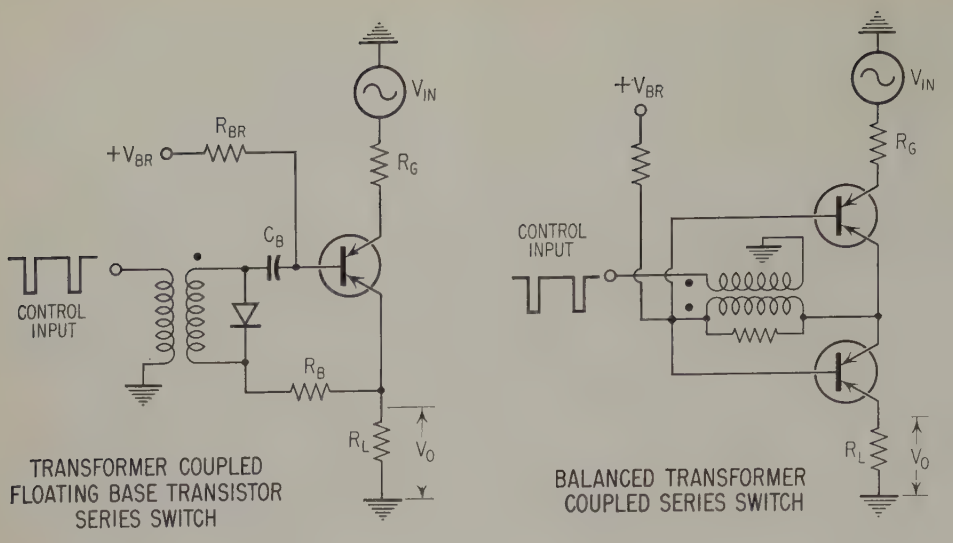

Fig. 13—Transformer coupled series switches.

thermal current of the transistor contributed to the *dc* component in the output of the shunt switch. Thermal currents also contribute to the *dc* components in series switches; however, the effect is less severe in series switches because of the lower impedance levels. It is extremely difficult to compensate for the thermal currents due to their considerable variation from unit to unit and with temperature. The direction of the *dc* components due to the thermal currents is opposite to that of the *dc* components produced by the base current. It is possible however, to make the compensating current slightly larger than the base current and variable with temperature in such a manner as to produce a *dc* component which is independent of the *off* or *on* condition.

The effects of thermal currents and *dc* components due to base current can be eliminated so far as the signal circuit is concerned through the use of transformers for both signal input and output. The effect of the *dc* component due to base current alone can be reduced using a transformer for either the signal input or the signal output.[2]

PRACTICAL TRANSISTOR BILATERAL SWITCH CIRCUITS

The circuit techniques which have been discussed can be applied to a large variety of signal switching applications. The selection of a particular circuit will depend on many factors. These factors include transistor availability, the *off* isolation and *on* attenuation requirements, the signal circuit impedance levels, and the tolerance on *dc* components. A number of circuits have been built and tested to prove the feasibility of transitor bilateral switches. Some of these circuits will be described in the following sections.

Experimental Pulse Amplitude Modulation System

An experimental two channel PAM system using bilateral switches as the modulators and demodulators and some of the waveforms obtained in this system are shown in *Fig. 14*. Since the driving waveform in a PAM system is characterized by constant pulse width and repetition rate, transformer coupled bilateral switches were used in the modulators and demodulators.

The driving waveforms (G_1 and G_2) shown in *Fig. 14*, are 5 μ*sec* pulses with a period of 120 μ*sec*, i. e., a pulse repetition rate of 8.33 *kc*, allowing the transmission of input information with frequency components up to approximately 4 *kc*. The gating pulses for channel 2 are delayed with respect to those of channel 1 by the desired channel spacing. The minimum channel spacing is dictated by the cross-talk requirement between the channels once the samplers, specifications are known. All samplers of this general type have some trail-off of the in-channel information into the adjacent channel. The magnitude of the trail-off and the channel spacing as well as the signal feedthru of the switches determine the amount of cross-talk between channels.

The waveform obtained at the base of one of the modulators is also shown in *Fig. 14*. The shaded areas of this waveform show the variation with input signal. The *on RC* time constant in the base circuit must be sufficiently long to provide adequate base current for saturation during the entire gate pulse. An *RC* time constant of 6 μ*sec* was used.

On the other hand, the *off* time constant must be long enough to hold the base *off* for the entire period (115 μ*sec*), but short enough to allow sufficient discharge so that the next forward pulse can saturate the transistor. An *RC* time constant of 87 μ*sec* was chosen.

The modulator output waveform of *Fig. 14* indicates the problems associated with this circuit. The most severe is the turn-on transient. This spike is due to the capacity feedthru of the leading edge of the gate signal. The other problem is the variation in turn-off characteristics with signal amplitude and the signal trail off (about 0.3 μ*sec* in this case). The use of symmetrical transistors with good high speed switching characteristics minimizes this difficulty.

The gating signals for the demodulators must be ynchronized with the corresponding gate signals of ie modulators. The outputs of the demodulators have rge time constants ($RC = 240\ \mu sec$) so that the high equency components due to the sampling are parally filtered. Since the load capacitor of the demodutors is .01 μfd the input impedance to the amplifier 25K. A low pass filter was employed to further reuce the sampling transients.

The performance of this system is as follows:

Input Signal — 3 volts peak, 4 *kc* max.
(The input amplitude was limited by the particular amplifiers used and not by the modulator or demodulator characteristics.)

Adjacent channel cross talk with 10 μsec channel spacing — $-70db$

Adjacent channel cross talk with 5.3 μsec channel spacing — $-60db$

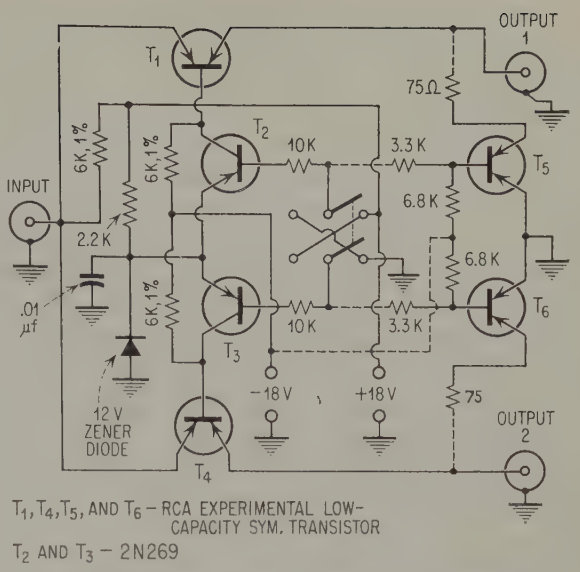

Fig. 15—Coaxial line switch using low capacity symmetrical transistors.

Coaxial Line Switches

Several of the techniques which have been described can be readily applied to coaxial line or high frequency signal switching. The choice of the particular circuit will depend upon two major factors, namely:

1. The transistor capacitances and extrinsic base resistance of available transistors
2. The *off* isolation required at high frequencies.

The circuit shown in *Fig. 15* employs a single transistor as the basic switch element. The switch transistors used in this circuit were experimental RCA transistors with C_{Cb} and C_{Eb} less than 3 $\mu\mu fd$ at 6 volts reverse bias and r_b less than 200 ohms. The penalty paid for low transition capacitance is usually reduced gain, consequently, β_N and β_I were as low as 10. This circuit could handle 3.0v peak to peak signal across 75 ohms, i.e., 20 *ma* of peak current, with good linearity. The

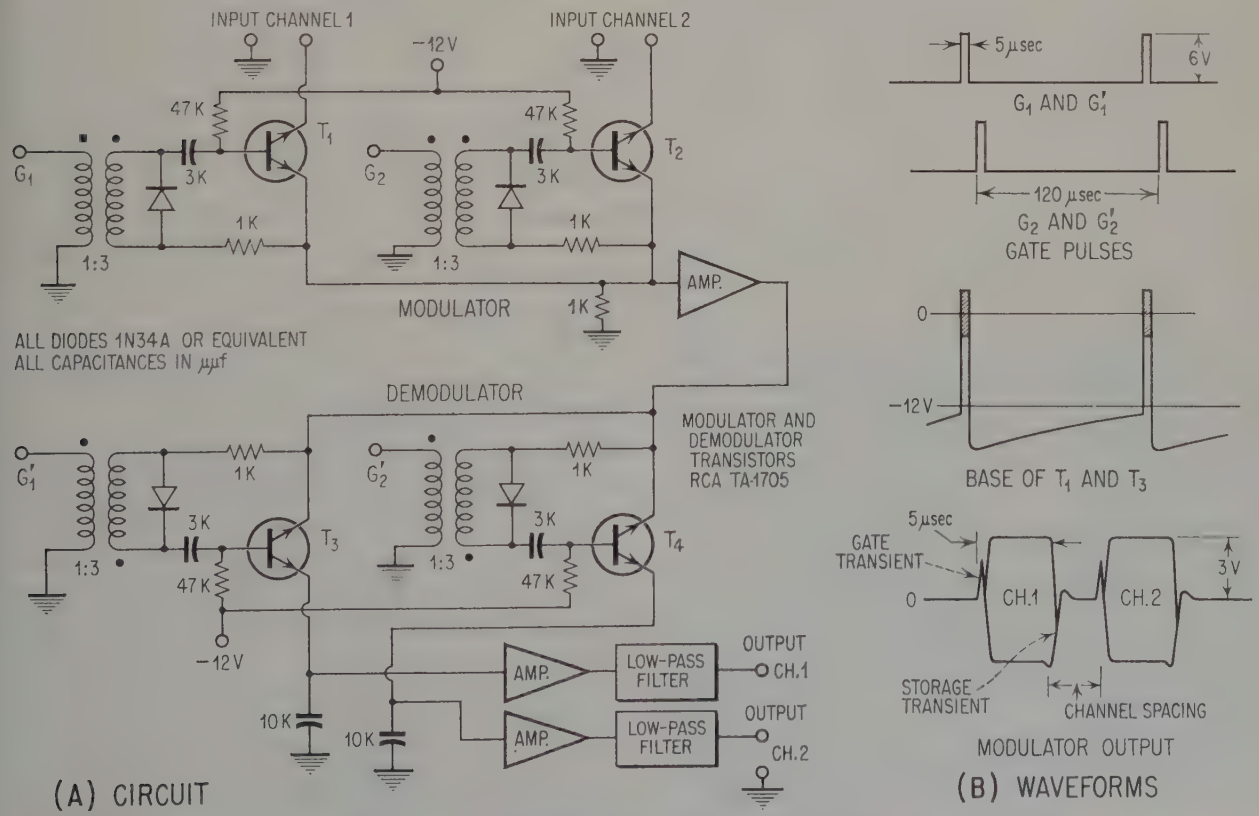

Fig. 14—Experimental two channel PAM system using bilateral switches as modulators and demodulators.

control transistors used were 2N269's. Since the control transistors carry current in only one direction, non-symmetrical units are satisfactory. The control transistors were driven from a single pole double throw *dc* switch to provide single pole double throw action in the high frequency lines. A flip-flop could be used to provide the same function. *Fig. 15* shows the common terminal at the input with separate outputs. This is not a necessary restriction and the functions can be reversed. When the circuit is used as shown, the load ends of both output lines should be terminated; then the input line always has approximately the correct termination. When the functions of output and input are reversed, the output line must still be terminated. The addition of the shunt switches as shown by dotted lines will provide constant termination for all lines. The operating characteristics of this circuit are as follows:

Off feedthru at 6 *mc* when terminated in 75 ohms	—60 *db*
On Attenuation from 0 to 6 *mc*	0.5 ± 0.1 *db*
dc shift across 75 ohms	10 *mv* max
*Linearity { loss	0.5%
*Linearity { phase at 3.58 *mc*	.05 degree
Total power dissipation (excluding shunt switches)	300 *mw.*

A computation of the *off* feedthru isolation of this circuit using the equations developed in Part I of this paper yields —75*db*. The difference between the measured and calculated values is due primarily to feedthru effects attributable to stray capacitance. It should be noted that 0.35 μμ*fd* of stray capacity between input and output will result in —60*db* feedthru. Consequently the layout and choice of circuit components is extremely important and should receive the utmost care.

In *Fig. 16,* a coaxial line switcher employing available developmental transistors is shown. The high transition capacitance, C_{Cb} and C_{Eb}, of 25 μμ*fd* maximum at 6 volts reverse bias, of both these units makes it necessary to use the complementary series arrangement for good isolation. The use of either of these transistors in the previous circuit would give approximately 46 to 50 *db* isolation at 6 *mc*. However, the use of the series complementary arrangement yields 58 to 62 *db* isolation at 6 *mc* when the switches are terminated in 75 ohms. Here again the switch was controlled by a mechanical switch which could be replaced by a control flip-flop. The considerations with regard to inputs and outputs that were discussed for the circuit of *Fig. 15* apply equally well to this circuit.

The operating characteristics of this circuit are as follows:

Off feedthru at 6 *mc* when terminated in 75 ohms	—62*db*
On attenuation from 0 to 6 *mc*	0.6 ± 0.1 *db*
dc shift across 75 ohms	12 *mv* max
*Linearity { loss	.6%
*Linearity { phase at 3.58 *mc*	.08 degrees
Total power dissipation	570 *mw.*

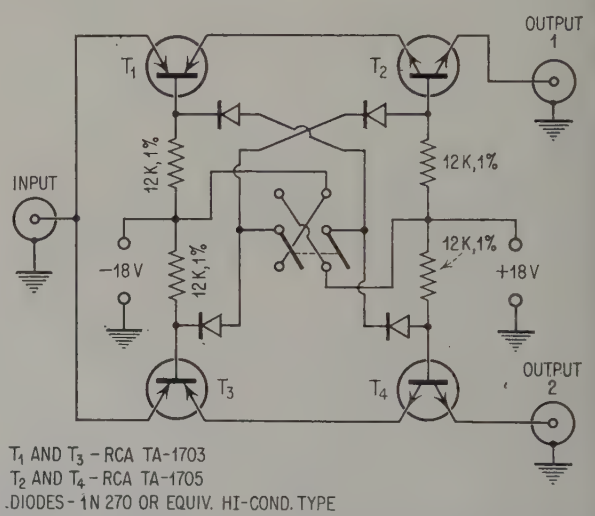

Fig. 16— Coaxial line switch using available symmetrical transistors.

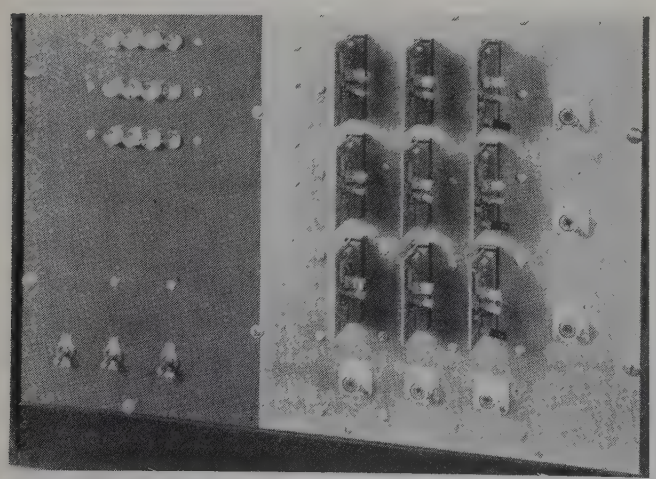

Fig. 18—3 input—3 output high frequency switching matrix.

High Frequency Switching Matrix

An experimental 3 input-3 output, high frequency switching matrix was constructed using the circuits of *Fig. 17*. The matrix was designed to switch between terminated transmission lines and high impedance isolation amplifiers. The high output impedance was required so that more than one output could be connected to any input without unduly affecting the input termination. The shunt switches in *Fig. 17* were used to ground each output when no input connection was desired. The high frequency crosspoints were controlled by push button mechanical switches. The mechanical switches were arranged so that the outputs could be stacked on any input, but only one input could be connected to any output at any given time.

*Linearity of loss and phase are defined as the change in *on* attenuation and phase shift with signal amplitude.

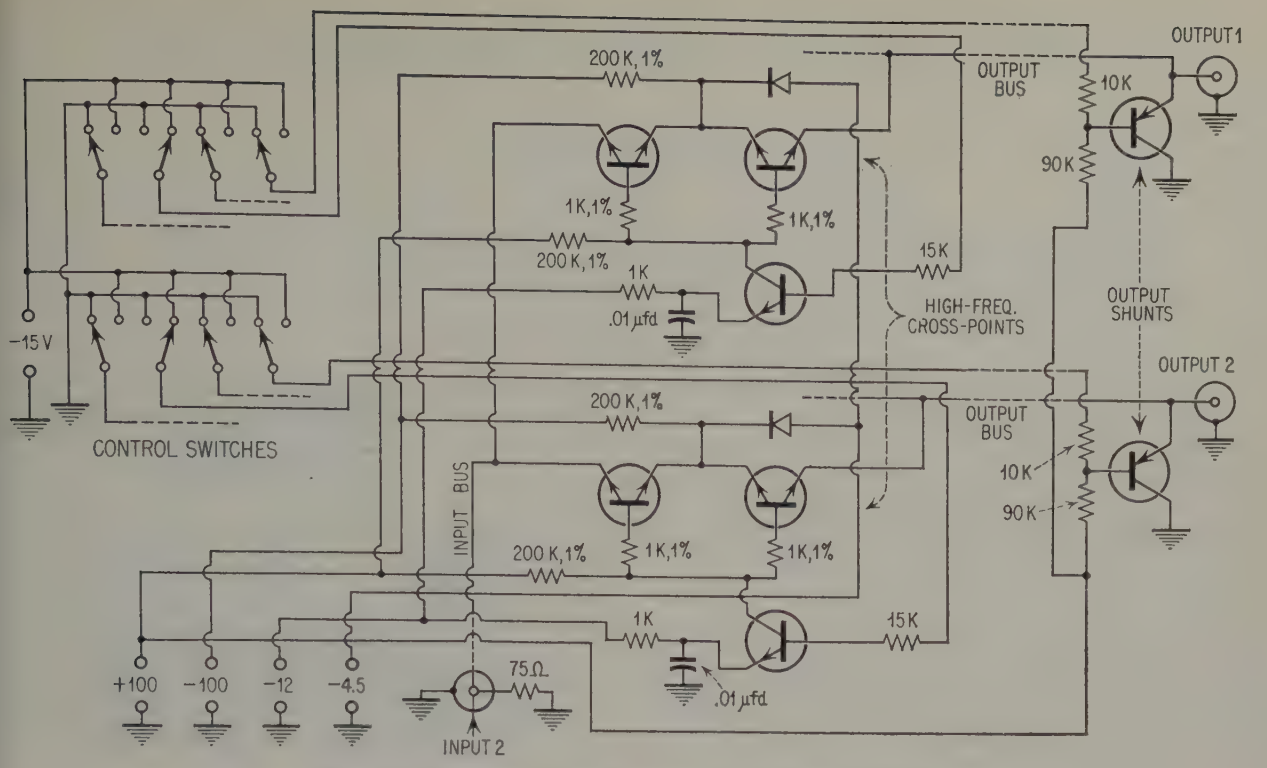

Fig. 17—Transistor high frequency switching matrix.

The transistors used in the switch were commercially available transistors selected for reasonable gains in both directions, i. e., β_N and $\beta_I \geqslant 20$. Commercial transistors were selected because of their better availability when the equipment was constructed. The complete switching matrix is shown in *Fig. 18.*

The operating characteristics of the matrix are as follows:

Feed thru with the output shunted at 4.5 *mc*	$>-75db$
Feedthru of a single cross point at 4.5 *mc*	$-62db$
Maximum cross-talk at 4.5 *mc*	$-46db$
On attenuation from 0 to 4.5 *mc*	$0.6 \pm 0.1db$
dc shift across 75 ohms	8 *mv* max
*Linearity loss	0.3%
*Linearity phase at 3.58 *mc*	.05 degree
Total power dissipation	1.5 watts

The rather high feedthru of the cross point ($-62db$) is due to stray wiring capacitance. The wiring feedthru with the crosspoint boards removed from the chassis was also $-62db$. The feedthru capability of the cross-point circuit neglecting all stray capacitance is less than -94 *db*. Using the RCA experimental low capacity transistors in a circuit similar to the cross-point circuit, feedthru of approximately -80 *db* at *mc* has been obtained. The cross-over time between two signals in the high frequency switches which have been described is determined by the mechanical control switches. When these circuits are driven by high speed transistor flip-flops the cross-over time between two signals is typically less than 1.0 μsec.

CONCLUSIONS

Transistors can provide effective means of switching *ac* signal paths. Using low junction capacitance transistors, *off* feedthru as low as -80 *db* at 6 *mc* can be obtained. The *on* attenuation and its variation with signal level is typically very low. Although the material which has been presented is primarily limited to high frequency series switches, it should be evident that the techniques presented are fully applicable to low frequency signal switching. The *off* isolation obtainable at low frequencies is typically greater than 80 to 100 *db*.

The circuit techniques which have been presented are by no means comprehensive. Many circuit configurations including combinations of series and shunt switches are possible. However, the majority of the difficulties encountered in the use of transistors as bilateral switches can be effectively overcome by choosing suitable transistors and using the circuit techniques which have been described. Transistor bilateral switches should prove useful in a variety of signal switching applications where high reliability is required. The fast switching time of transistors as compared to relays offers interesting possibilities, particularly in the area of visual data handling and processing.

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A Transistorized Radio Direction Finder

HOWARD GRONEMEIER*

Because of its specialized marine application, the design of this receiver involves electrical specifications and other requirements not encountered in conventional portables. The author discusses problems and solutions with emphasis on unusual circuitry.

THE DESIGN of a radio direction finder seems at the first glance to be practically the same as that of a conventional commercial broadcast receiver. But upon closer examination, significant differences emerge which must be taken into consideration. It is these differences which will be stressed in this discussion, rather than the general problem of designing a radio receiver.

Electrical specifications can be listed as follows:

Band coverage. The receiver covers a frequency range from 200 *kc* to 3.4 *mc* in three bands: Beacon, 200 to 400 *kc;* Broadcast, 550 to 1600 *kc;* Marine, 1.7 to 3.4 *mc*. The unit is useful as a direction finder on all three bands.

Power output. Undistorted output power is one watt, which is great enough to overcome ambient boat noise and small enough for long battery life.

Selectivity. Since the beacon station bandwidths are very narrow, the *i-f* selectivity is as narrow as practicable.

Sensitivity. Sensitivity is about 50 microvolts/meter. This level is chosen to permit the reception of all beacon stations at their published ranges. The receiver is designed to deliver a 0.5-watt signal which is 6 *db* different in amplitude with and without 50% modulation when excited by a field strength of 50 to 100 microvolts/meter.

Batteries. Principal considerations are availability, cost, and life. The set uses four lantern cells of a standard type commonly available at low cost, sometimes at less than $1.00 each. They will last through a boating season at the very minimum. In many cases shelf life will probably be a limiting factor.

Automatic volume control. Since the receiver is to serve at times as an entertainment device, it includes *a-v-c* in one switch position. This feature also aids in tuning the receiver.

Direction finding. A switch position is provided to depress the receiver gain a fixed amount with varying input signal. This serves to provide a sharp null when the antenna is rotated to a position of minimum signal reception.

Null meter. In addition to the null indication provided by the speaker, visual indication, which can be perceived far more accurately than aural indication, is provided by a meter. To provide still greater accuracy, the meter works independently of audio, modulation.

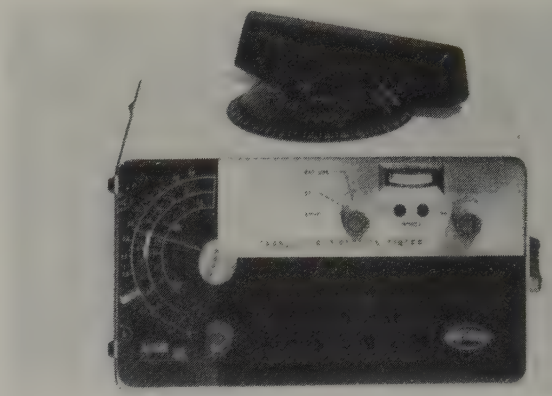

Fig. 1—Transistorized radio direction finder

Battery check. A metering circuit indicates the condition of the batteries under load and permits an estimate of their remaining life.

Water. Since the unit is intended primarily for marine use, it is designed to resist water splash and salt spray.

Heat. Heat is a factor which must be considered in designing transistorized devices. The heat generated within the receiver is practically negligible, but if the unit is left on a boat-deck fully exposed to the sun, the temperature of the air inside the case may rise to a level which is dangerous to transistors. The case is therefore designed to supply enough air circulation and the color chosen to reflect enough heat so that the internal temperature will not exceed the safety limit of 85°C under any reasonable summer conditions. Specifically, the transistors must be safe and all circuits operative with the unit fully exposed to the sun on a day when the surrounding air is at 85°F.

Dimensions. The unit measures roughly 13½ x 7½ x 9 inches. Extreme compactness was not an objective, since miniaturization of the chassis would have had little effect on over-all space requirements involving air circulation for cooling, a speaker cone and baffle of adequate size for broadcast listening, batteries of ample capacity, and easy access for servicing. Furthermore, the antenna coil is already slightly longer than the depth of the case and could not be shortened without loss of efficiency.

*Commercial Equipment Engineering, Raytheon Manufacturing Company, Waltham 54, Massachusetts

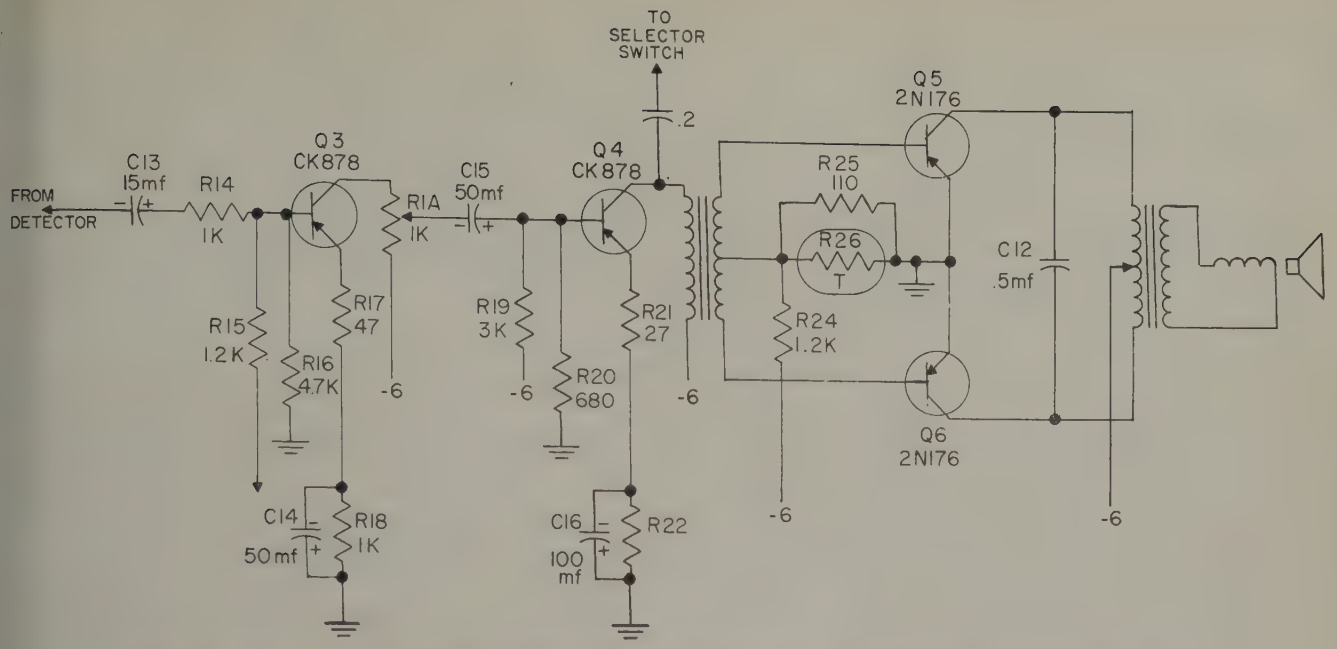

Fig. 2—Circuit diagram of audio amplifier. R22 is 330 ohms. R15 (1.2K) connects to bias source.

Transistors. Transistors are used in the interest of reliability, long life, and low power consumption.

Printed circuitry is used, but only where the circuitry is common to all bands, that is, from the input of the *i-f* amplifiers through the audio output. The complex switching preceding the *i-f* amplifiers lends itself more easily to conventional wiring techniques.

Figure 2 is the circuit diagram of the audio system. *Q3* is a CK878 transistor which amplifies the audio fed from the second detector. It has a 1000-ohm resistor in series with the base, which reduces the gain somewhat. The 47 ohm resistor in the emitter circuit also reduces the gain. But both of these elements increase the impedance seen by the second detector diode and allow it to work more linearly. The audio amplifier load is made up by the volume control in shunt with whatever load is provided by the following driver stage.

The driver stage, which employs *Q4*, another CK878 type transistor, is likewise made degenerative by an unbypassed resistor in the emitter circuit to decrease the loading effects on the previous circuit. *Q4* operates with about 4.5 *ma* of collector current and is capable of supplying enough power to overdrive the output stages. Its load is the primary of the phase splitting transformer which supplies push-pull drive to the power stage.

The output circuit employs *Q5* and *Q6*, a pair of 2N176 transistors which operate very close to Class B. There is some idling current through each transistor without an input signal. This is to avoid crossover distortion which occurs with true Class B operation.

Thermistor *R26* is used to maintain the proper operating point for the transistors over a range of temperatures. As the temperature rises, the collector current tends to increase due to the increase in I_{co} flowing in the resistance between base and ground. This effect is canceled by the thermistor resistance, which varies with temperature. The required resistance was determined empirically by actually varying the temperature of the circuit and plotting the resistance values required to maintain a constant collector current. The thermistor and shunt resistor combination closely follows the original resistance plot.

The output transformer presents a 50 ohm load from the 3 ohm voice coil of the speaker, which drives a 4″ x 6″ oval cone. A jack is provided directly across the primary of the output transformer so that high-impedance headphones may be used for easier listening under the high ambient noise conditions encountered on a motor-boat. The intentional impedance mismatch serves to prevent excessive volume in the headphones.

The *i-f* amplifier, shown in *Fig. 3*, is conventional. Double-tuned circuits are used for improved skirt selectivity. The response is about 7 *kc* wide at the 3 *db* points and about 25 *kc* wide at 30 *db* down. Both stages (*Q1* and *Q2*) are neutralized, and the condenser values were determined by experiment. 2N484 transistors were selected because the collector capacitance of this type is held to a limited range and individual neutralization for individual units is not necessary. According to measurements, the peak of the response curve shifts only about 500 cycles with changes in bias. The emitter and base *d-c* resistances were selected to provide good temperature stability. An effort was made to keep the base return resistance in each circuit no more than three times the value of the emitter resistance, but this is impossible when the switch is in the "Broadcast" position, since the

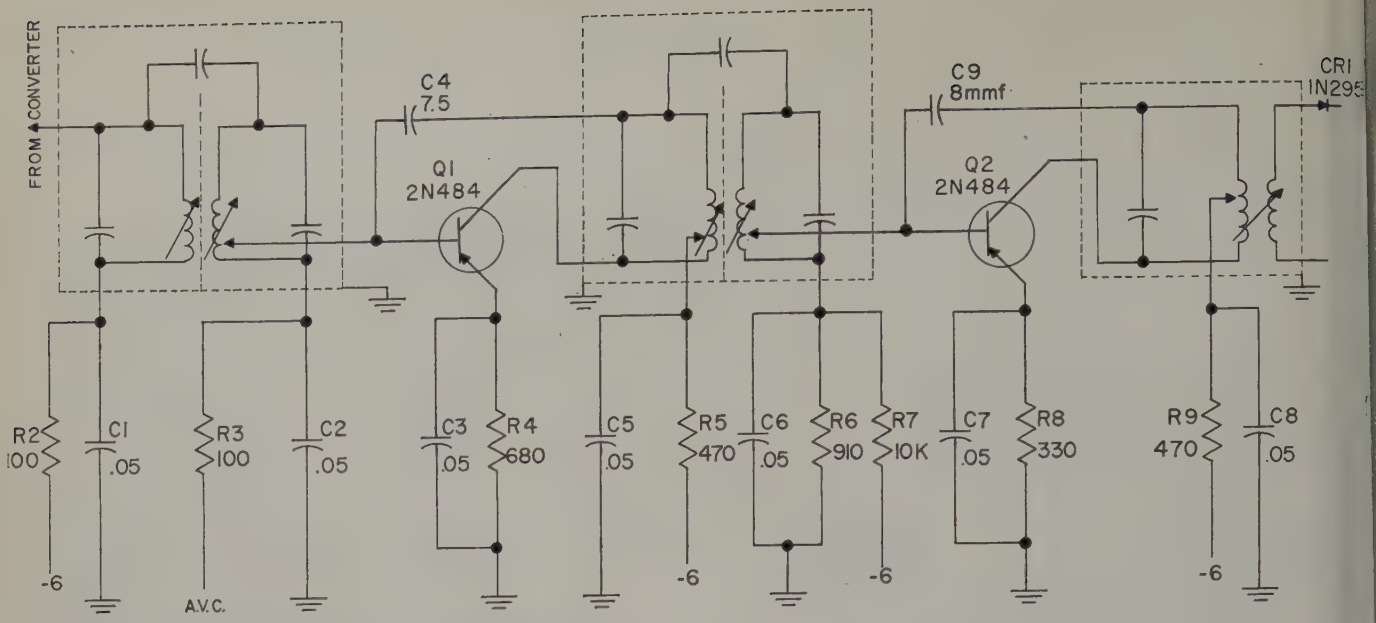

Fig. 3—Circuit diagram of i-f amplifier.

first *i-f* stage then has a base return through about 7500 ohms. However, even if the receiver should become inoperative on the broadcast band under severe temperature conditions, operation can be restored by placing the switch in the "Direction Finding" position, where the maximum return in the base is 750 ohms. In this position, the bias fed on the *a-v-c* line is determined by a 500 ohm control which operates in tandem with the volume control.

The second detector circuit is unusual enough to require some preliminary explanation. *Fig. 4* shows the characteristic curve of a diode. The lines drawn tangent to the curve indicate the resistance presented by the diode at the point of tangency. As the diode current increases from zero, its dynamic resistance decreases. Thus, if the diode is forward-biased to a point where it still retains its nonlinearity but its dynamic resistance is reduced, it can better be matched into low impedance circuits. Small voltages such as occur in low-impedance circuits do not drive the diode into the low-impedance area of its charecteristic. Power gain can be obtained by improving the match in this manner, and the diode detects more linearly with different levels of modulation.

Figure 5 shows how this is accomplished. *R13, R12,* and *R10* make up a bleeder from the power supply. The voltage across *R12* is applied across the meter, *R11,* and the diode, all of which are in series. This causes a current of 4 to 5 microamps to flow through the diode in the first three switch positions, thus supplying the desired forward bias.

In the fourth position of the switch, *R23* becomes a load resistor across the battery, and the meter measures the current through *R31* so as to indicate the battery voltage under load. The switch is spring-loaded in the fourth position so that it returns to the third position when released. This is to avoid accidentally leaving the load on the battery.

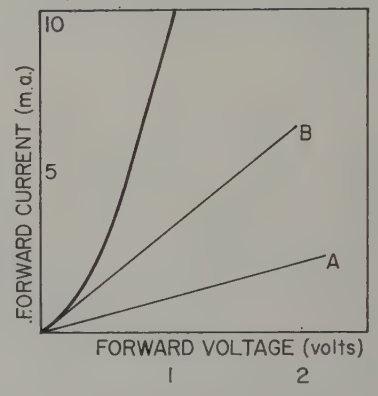

Fig. 4—The heavy line is the curve of a diode characteristic. The slope of lines A and B represent the dynamic resistance of the diode at the point of tangency.

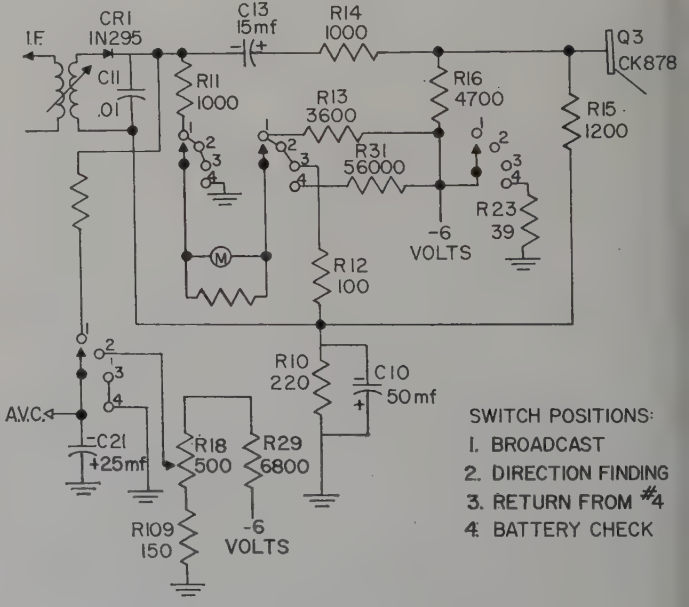

Fig. 5—Second detector and switching circuit.

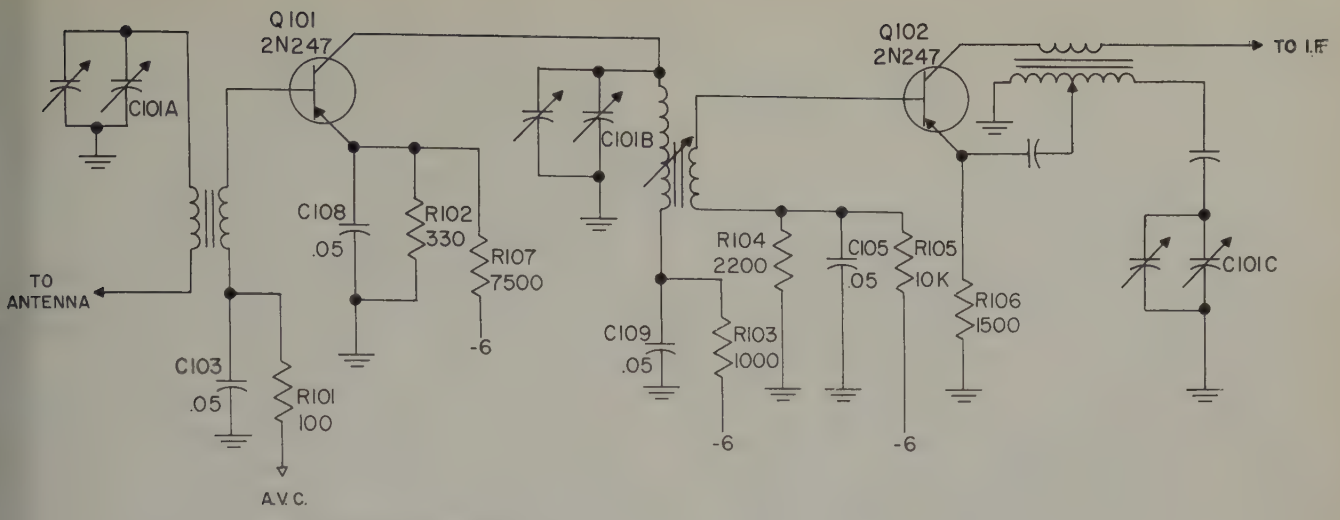

Fig. 6—R-F amplifier 2nd converter showing reception of only one band.

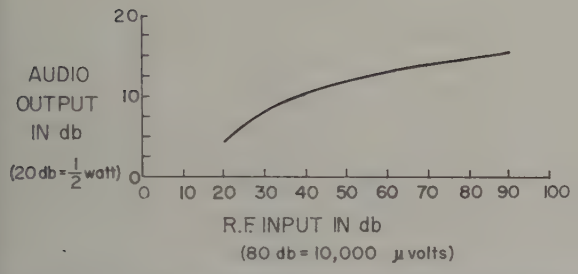

Fig. 6A—A-V-C characteristic at a nominal setting of the volume control.

Radio frequency amplifier *Q101* and converter *Q102* are both 2N247 transistors. Three advantages of this type are low collector capacitance (1.7 μμf) which requires no neutralization; a good gain up through and beyond the specified frequency limit of 3.4 *mc*, and a relatively low noise figure. The signal is fed to the base of the *r-f* amplifier by means of a secondary winding which is coupled to the adjustable inductance in the antenna circuit. This makes it possible to supply gain control to the *r-f* stage as well as to match the input of the transistor.

Figure 6 is a simplified diagram showing the basic circuit. In the actual circuit, the various tuning elements are switched in and out to provide reception throughout the three bands. The emitter voltage is provided with a relatively heavy current bleeder to hold the emitter voltage somewhat "stiff" with changes in emitter current. This reduces the *d-c* degeneration of the circuit and improves the *a-v-c* gain. The measured *a-v-c* characteristic is shown in *Fig 6A*.

The signal from the *r-f* amplifier collector is coupled to the converter through a secondary winding to match the input impedance of that stage. Tuning circuits in the *r-f* amplifier output were originally tapped for connection to the collector at a lower impedance. However, spurious responses were encountered, and it was found necessary to drive into the total of the tuned circuit and avoid the taps. This actually increased the gain but introduced some instability, which was remedied by series resistors in the emitter and collector leads as shown in *Fig. 6*.

The converter operates as an oscillator with feedback from collector to emitter. The collector current passes through a winding which is coupled to a tuned circuit in the emitter circuit. The tuned circuit is tapped to reduce loading and provide matching to the emitter. The collector current contains the *r-f* signal, the oscillator signal, sum and difference frequencies, and various harmonics. This current is fed through the primary of the first *i-f* transformer which presents a high impedance at 455 *kc* which is the *i-f* frequency.

Power delivered from the antenna to the input circuit was determined in the following manner: The maximum voltage induced in the loop is[1]

$$E = 2\pi\epsilon\frac{NA}{\lambda}$$

and the radiation resistance is[2]

$$R_r = 31.2 \times 10^3 \left(\frac{NA}{\lambda^2}\right)^2$$

where ϵ is the field strength in volts per meter
N is the number of turns in the loop
A is the area of the loop in square meters
λ is the wavelength in meters

From this information it can be shown that if perfectly matched to a load the antenna would deliver to the load a power equal to

$$P = \frac{(\pi\epsilon)^2}{31.2 \times 10^3} \times \lambda^2$$

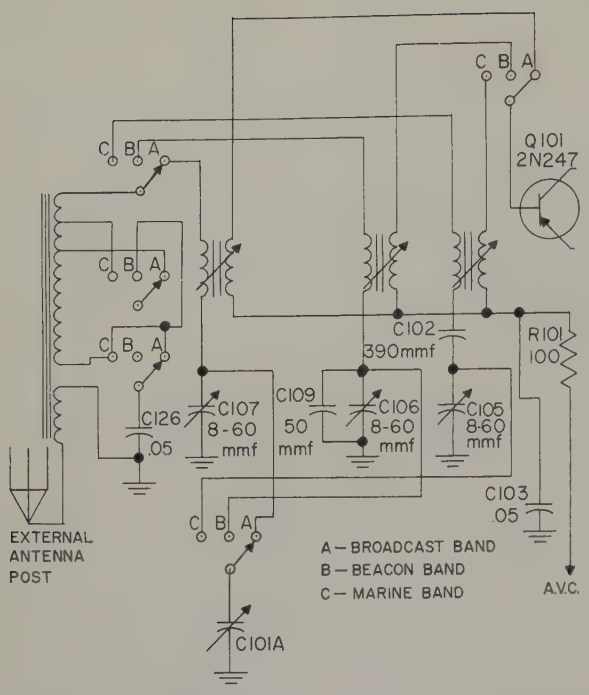

Fig. 7—The diagram illustrates the manner in which the loop antenna is switched to accommodate the three bands.

which is independent of the number of turns and the area of the loop.

Because the radiation resistance is so small, we match to the resistance in the circuit which is the determining factor in the circuit *Q*. This means that only half of the available power gets to the load, the other half being consumed in the circuit resistance. And taking into account the mismatch between the radiation resistance and the combined circuit resistances, the final result shows the power delivered to the load to be

$$P = \frac{(\pi\ \epsilon)^2}{R_L}\left(\frac{NA}{\lambda}\right)^2$$

In the case of a rod antenna, the area of the loop is multiplied by μ_{eff} where

$$\mu_{eff} = \frac{\text{inductance of coil with rod}}{\text{inductance of coil in air}}$$

and the final equation becomes

$$P_L = \frac{(\pi\ \epsilon)^2}{R_L}\left(\frac{NA\ \mu_{eff}}{\lambda}\right)^2$$

which assumes that R_L is much greater than the radiation resistance, the usual case. Using the above equation, it can be determined how much gain is required in the receiver as well as what the minimum signal strength must be to obtain a given signal-to-noise level.

To obtain maximum power to the input, the turns should be made as large in number as possible, and μ_{eff} should be as large as possible. The number of turns is limited by the amount of inductance that can be tolerated at any frequency to obtain tuning and tracking. Another problem is hand capacity which affects the action of the receiver when the antenna is moved for direction finding.

The ratio, μ_{eff} can be increased by increasing the L/D ratio of the coil, where L is the length of the coil and D is its diameter. Since all of the effects are interactive, the best compromise must be found.

In the described receiver, the turns on the antenna provide about one-half of the total required inductance. These turns are spread out as much as practicable to obtain the greatest L/D ratio. As seen in *Fig. 7*, taps are brought off the antenna to the selector switch to change the number of turns for each band. Another portion of the switch places a capacitor across the unused windings to move the self-resonant frequency to a region well below the received band.

The battery supplies are split up to avoid heavy filter circuits. All of the ouput power is taken from a separate supply so the fluctuations in voltage will not be reflected into any of the preceding circuits.

It has been found necessary to place a 0.2 μf capacitor from collector to ground of the audio driver stage. High man-made noise peaks generate harmonics which would be received by the antenna when tuned to about 200 *kc*.

The *r-f* amplifier, is of course, very important in determining sensitivity. In about 10% of the receivers it may be necessary to select transistors to meet receiver specifications.

The first production receivers indicate that the original specifications are being met. Tests show that 180 degrees of antenna rotation changes the reading by a maximum of 0.5 degree. On readings made to transmitters within sight, the indicated bearing was repeatedly found to be within ± 1 degree of the line-of-sight reading.

[1,2]From Terman, *Radio Engineers' Handbook*, 1943, p. 813, 814.

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications Jan. 1948 to May 2, 1950

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from 1948 to 1950. In subsequent issues patents issued from 1951 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear every three months, the treatment given to each item being more detailed.

January 27, 1948

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March 16, 1948

2,437,995 Selenium Rectifiers;—W. E. Blackburn; Assignee: Westinghouse Electric Corp.; The process of making selenium units.

April 6, 1948

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*Source: Official Gazette, United States Patent Office.

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April 27, 1948

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2,446,238 Selenium Rectifier Plate;—G. F. Mueller; Assignee: Fansteel Metallurgical Corp.; Method of producing blocking layer devices by treating the selenium layer with benzo-phenone vapors.
2,446,239 Selenium Rectifier Disk;—G. F. Mueller; Assignee: Fansteel Metallurgical Corp; Method of producing blocking layer devices by treating the selenium layer with benzaldehyde vapors.
2,446,465 Selenium Rectifier;—S. S. Fry; Assignee: Fansteel Metallurgical Corp.; Method of producing blocking layer devices by treating the selenium layer with α-benzildioxime vapors.
2,446,468 Selenium Rectifiers;—S. S. Fry; Assignee: Fansteel Metallurgical Corp.; A blocking layer device the counter-electrode of which is composed of bismuth, tin, lead, cadmium, and magnesium.

August 10, 1948

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November 2, 1948

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2,452,603 Metal Contact Rectifier;—O. Saslaw; Assignee: Federal Telephone and Radio Corp.; A metal contact rectifier which has a selenium layer fused to a base plate.

November 16, 1948

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November 30, 1948

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December 28, 1948

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February 8, 1949

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February 22, 1949

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March 1, 1949

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2,462,911 Rectifier;—M. F. Skinker; Assignee: Federal Telephone and Radio Corp.; A rectifier stack.
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2,462,949 Method of Treating Selenium;—F. de Boer; Assignee: Hartford National Bank and Trust Company; Selenium for a blocking layer rectifier is prepared by heating a mixture of zirconium tetrachloride and selenium dichloride.

March 8, 1949

2,464,006 Method of Reducing Leakage Current in Selenium Rectifiers;—N. W. Addink, C. L. Boucher, C. de Lange, J. Kramer; Assignee: Hartford National Bank and Trust Company; A process for conditioning a selenium rectifier.

March 22, 1949

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March 29, 1949

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April 26, 1949

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Company; The method involves the precipitation of an ionically disintegrated element from the group consisting of selenium and sulfur.

May 3, 1949

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May 10, 1949

2,469,393 Rectifier;—I. Levin; Assignee: None; A method of making an iron oxide-magnesium rectifier unit.
2,469,418 Producing Silicon;—M. M. Striplin; Assignee: Tennessee Valley Authority; A process for the production of elemental silicon in high purity.
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May 31, 1949

2,471,898 Reclamation of Selenium Rectifier Cells;—D. W. Rau; Assignee: Vickers Inc.; The method consists of dipping the cells in an electrolyte of an organic amine, aging the dipped cells for from 12 to 48 hours, and reforming the cells.

June 5, 1949

2,472,378 Detection of High Frequency Electric Oscillations;—J. L. Lawson; Assignee: United States of America (Navy Dept.); Apparatus for the detection of radio signals in cooperation with a rectifier element which may be of the silicon crystal type.

June 14, 1949

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2,473,419 Alternating Current Rectifier;—A. C. Fletcher, D. Loyd; Assignee: None; A rectifier assembly consisting of semiconducting plates arranged to allow large passageways for air circulation.

July 5, 1949

2,474,809 Dry-Plate Rectifier Unit;—J. G. Abbott; Assignee: The United States of America; A selenium oxide rectifier unit comprising corrugated inner and outer shells.

July 12, 1949

2,475,810 Preparation of Silicon Material;—H. C. Theurer; Assignee: Bell Telephone Laboratories; The method involves the handling of hot fused silicon and the controlled cooling thereof.
2,475,940 Crystal Contact;—F. H. Brittain; Assignee: The General Electric Co., Ltd.; In a semiconducting device, a thin layer of solid polymerized *n*-butyl methacrylate covering the surface of the crystal around the end of the metal wire in order to prevent movement of the wire with respect to the point of contact.
2,476,042 Selenium Rectifier and Method of Fabrication;—C. W. Hewlett; Assignee: The General Electric Company; A selenium rectifier cell capable of rectifying alternating current in excess of 50 volts.
2,476,066 Crystal Matrix;—N. Rochester; Assignee: Sylvania Electric Products Inc.; A rectifier matrix having 2^N lines and n channels and for which germanium crystal rectifiers are suitable.

July 19, 1949

2,476,800 Rectifier;—W. E. Blackburn; Assignee: Westinghouse Electric Corp.; A method of forming of a barrier layer on the selenium surface.

July 26, 1949

2,476,989 Selenium Rectifiers and Method of Manufacturing the Same;—J. Martinet, M. Deshays; Assignee: International Standard Electric Corp.; A method that treats the rectifier with selenium anhydride and then with an acrylic aldehyde, RCHO where R belongs to the group consisting of hydrogen and a lower alkyl radical.

August 9, 1949

2,478,749 Combination of a Blocking Layer Rectifier Plate Having a Cooling Plate Pressed on It;—C. DeLange, D. M. Duinker; Cooling plate is in intimate thermal contact with the rectifying plate.

August 16, 1949

2,479,301 Selenium Rectifier;—W. E. Blackburn; Assignee: Westinghouse Electric Corp.; A selenium surface is produced and immersed in a water solution of .001 normal concentration of thallous hydroxide.
2,479,446 Method of Manufacturing Small Current Selenium Rectifiers;—E. D. Wilson; Assignee: Westinghouse Electric Corp.; The method involves the production of counter-electrode sheets of large area, the covering of these sheets with stiff paper, and the subdivision of the sheets into small rectifiers.

August 30, 1949

2,480,124 Manufacture of Selenium Elements Such as Rectifiers;—D. L. Driver; Assignee: Standard Telephones and Cables Limited (A British Company); The localized solid electrically insulative mass is placed upon the selenium layer prior to the hotpressing during the production of a stratified selenium cell.

September 13, 1949

2,481,739 Rectifiers;—M. Goodman; Assignee: Radio Receptor Company, Inc.; The method involves the surface treatment of crystalline selenium layer with a stable solution of a non-interacting oxidizing and reducing agent.

September 27, 1949

2,482,777 Rectifier;—A. E. Howe; Assignee: Federal Telephone and Radio Corp.; A rectifier comprising a metal plate on which is placed a semiconducting layer.
2,482,817 Rectifier;—D. Vitrogan; Assignee: Federal Telephone and Radio Corp.; A dry selenium rectifier stack.

October 11, 1949

2,484,204 Selenium Rectifier;—W. E. Blackburn; Assignee: Westinghouse Electric Corp.; A d-c back voltage is applied to the oil immersed rectifier.

October 18, 1949

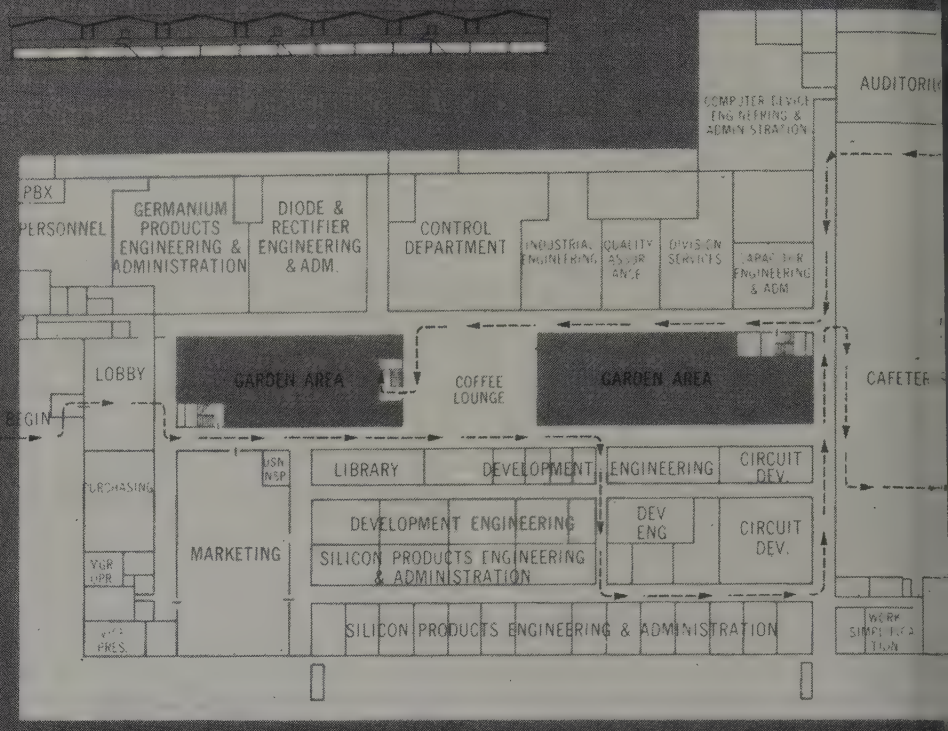
2,485,069 Translating Material of Silicon Base;—J. H. Scaff, H. C. Theurer; Assignee: Bell Telephone Laboratories; The method of making a translating device comprises casting an ingot of high purity silicon and adding a definite percentage of boron in order to control the electrical resistance.
2,485,402 Electric Rectifier and Method of Production;—W. H. Meiklejohn; Assignee: General Electric Company; The method of attaching an electric terminal to a copper oxide rectifier.

[*Continued on page 56*]

plant layout and tour routes

on the first floor . . .

About 600 of the division's 2,500 employees work here in administrative and engineering activities. Smooth, easy work flow among related groups is the prime layout objective in this 105,000-sq ft area. In the various engineering areas, fledgling inventions are developed into producible products. In other areas are the people who help insure the product's future through quality assurance, marketing and customer service. Included for divisional or company-wide meetings is a new 250 seat auditorium. Some 40,000 sq ft of miscellaneous service areas are utilized throughout the building.



New Forms

EXPEDITE A FAST-MOVING INDUSTRY

Modern and forward looking concepts in manufacturing plant design are typified by the new Texas Instrument Semiconductor-Components plant, officially opened on June 24, 1958. This is the first of a number of buildings to be erected on a 300-acre site. The next building to follow will be the Central Research Laboratory which will occupy 73,000 square feet.

To meet the requirements of built-in operational flexibility needed to keep pace with constantly changing processes and shifting process locales typical of an ever-expanding plant, two simple concepts were embodied in the overall planning and design. One is a 9-foot space frame between the two floors, and the other a roof of umbrella-shaped hyperbolic paraboloids in thin-shell concrete. The space frame, of precast, prestressed V-struts and yokes between floor slabs, encloses the many utility pipes necessary to manufacturing. From here conduits for various electrical, gas, water, air, vacuum, and waste facilities extend up to the manufacturing areas and down into the engineering laboratories in a regular pattern of outlets which can be tapped to serve any arrangement of equipment.

The first floor houses administrative and engineering offices and laboratories. On this floor also are located centralized lounges, library, conference rooms, rest rooms, and a 400-seat cafeteria. The top floor contains the manufacturing department and extends over almost 150,000 sq. ft. With the exception of those surrounding the central gardens, it is almost entirely free of dividing walls. The 4-ft. hollow-square columns, at 63 ft. intervals, in addition to supporting the concrete roof, also enclose the sprinkler system risers, drainage and vent pipes, and the air conditioning diffusing system.

Sixty thousand sq. ft. of the manufacturing floor are devoted to a "Snow-White" area in which are performed the most critical of the manufacturing and assembly processes. It is sealed from the remainder of the second floor area and the rest of the building by glass and masonry walls. A group of combination air locks and locker rooms is located at various entry points to the "Snow-White" area. All personnel enter-

ng this ultra-pure area must pass through a negative ressure air lock and don special lint-free smocks and aps.

Within the Snow-White area atmospheric environ-ient equal in controlled purity to that of a hospital urgical ward is maintained at all times. In this area, vhere such precise operations in device assembly are erformed as that of bonding a wire finer than a uman hair, less than one-thousandth of an inch nick, running through a bar of silicon the size of a ghter flint, the air is kept at a constant 20 percent elative humidity and the temperature at 75 degrees 'ahrenheit. Three air filtration methods are used to eep the air better than 99 percent dust free.

A new-type diffused lighting system using indirect, olor-corrected, mercury vapor lamps is installed in he manufacturing area. Engineers determined the ngle of light and number of fixtures required through se of a full-scale 4,000 sq. ft. mock-up of one unit ay. Lighting for the office and engineering areas is f the luminous ceiling type.

A unique IBM remote-control system monitors all he lighting in the building. All lights except the afety night light are switched off and on automati-ally at predetermined times by this control system.

The entire building was designed so that no objec-ionable sunlight glare, or heat, can enter the work-ng areas. In the non-"Snow-White" areas tempera-ures throughout are maintained at a constant 78 degrees, even when they rise to 100 degrees or more outside. Humidity is maintained at 50%.

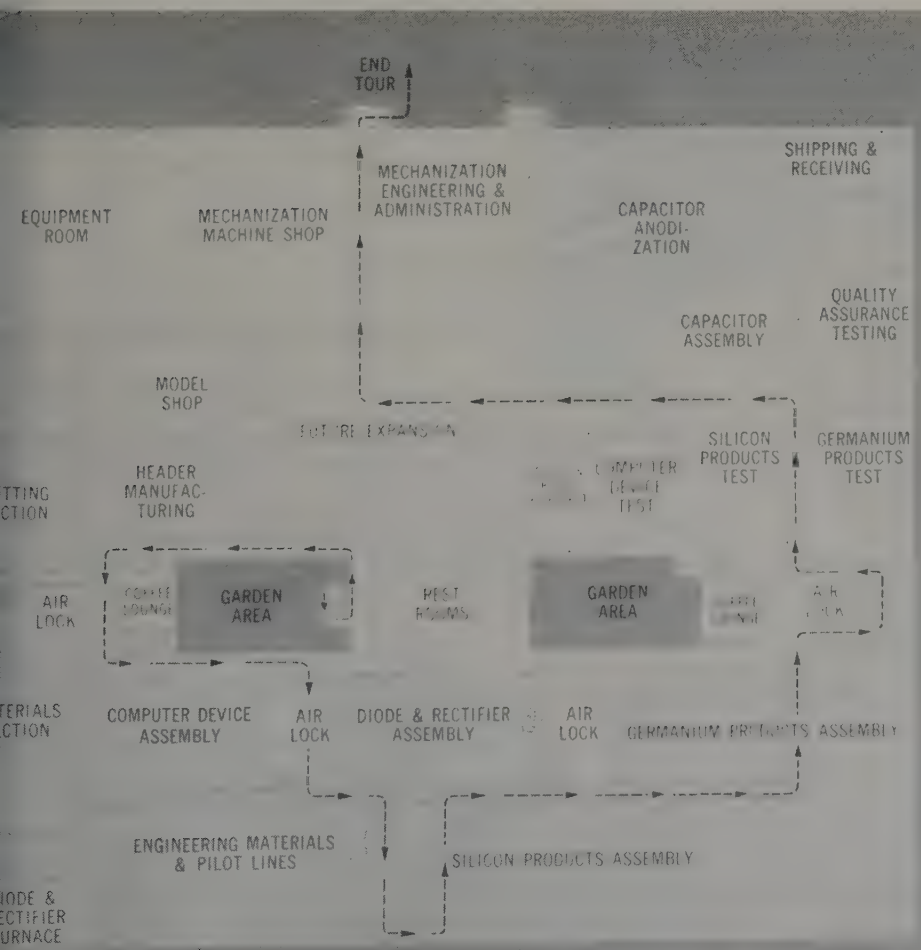
The mechanical equipment room extends over two levels, the lower or ground floor level having an area of about 9,000 sq. ft. and the upper level approximately 5,000 sq. ft. The lower area contains the refrigeration equipment for the air conditioning system, the main steam boiler, air compressor, the deionized water equipment, and electrostatic air filtering equipment.

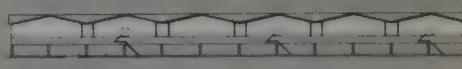
At the second level of the mechanical equipment space, which is 12 ft above ground level, is a mezzanine area which includes plant engineering offices, work shops, rest rooms for maintenance personnel, and the unit sub-stations required for supplying power to the units located in the mechanical equipment room.

Two employee parking lots adjacent to the building have a capacity of 2,500 cars. A third, for visitors, holds 80 cars and is located near the front entrance.

Expressing the philosophy behind the construction of this new project, TI President Patrick E. Hagerty has said:

"You can't just construct buildings to work in. They must be designed for their purpose, for people and machines. They must be good art as well, must express the company, its people and the society of which they are a part. It is our sincere desire that this first building and the entire development be a source of pride to the community and to our people."





almost 165,000 sq ft devoted to the manufacture of TI's more than 150 types of semiconductor and other electronic components. Pleasant and efficient working conditions result largely from a building plan eliminating space-stealing supports, wall breaks and overhead clutter. A specially engineered lighting system insures equal distribution of light at work bench level. The Snow White area—almost 40% of the manufacturing floor—provides an atmosphere precisely controlled as to temperature, humidity and contamination as the special environment for ultra precise operations.

Snow White Area

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Breakdown in Silicon	Physical Review May 1, 1958	Voltage-current, light multiplication, and small-signal *a-c* impedance characteristics of reverse-biased silicon *p-n* junctions are studied in the breakdown region.	B. Senitsky J. L. Moll
Birefringence Caused by Edge Dislocations in Silicon	Physical Review May 1, 1958	Calculation of intensity distribution in beam of plane polarized or circularly polarized infrared light through a crystal of silicon containing a single-edge dislocation.	R. Bullough
Temperature Dependence of Internal Friction in Germanium	Physical Review May 15, 1958	The internal friction of germanium has been measured as a function of temperature at 100 KC.	P. D. Southgate
Magnetoresistance Oscillations in Single-Crystal and Polycrystalline Indium Arsenide	Physical Review May 15, 1958	Measurement of the electrical resistivity of single-crystal and polycrystalline samples of *n*-type InAs have been made to 29,000 Gauss at temperature between 1.25°K and 20.2°K.	R. J. Sladek
Oscillatory Galvano-magnetic Effects in N-Type Indium Arsenide	Physical Review May 15, 1958	The Hall coefficient and resistivity of *n*-type InAs measured as a function of magnetic field strength reveal de Haas-van Alphen type oscillations.	H. P. R. Frederikse W. R. Hosler
Transistor Cutoff Frequency Measurement (Correspondence)	Proceedings of the I.R.E. April 1958	Discussion of advantages that may be gained by feeding the signal to the base in the measurement of alpha cutoff frequency.	L. G. Cripps
A Gallium Arsenide Microwave Diode	Proceedings of the I.R.E. April 1958	Device feasability evaluation indicates that gallium arsenide is potentially superior to germanium and silicon in point contact diodes.	D. A. Jenny
A Transistorized 150-MC FM Receiver	Proceedings of the I.R.E. April 1958	A completely transistorized experimental 150 *mc* FM receiver using diffused base transistors is described.	W. J. Giguere
Germanium N.P.I.N. Junction Transistor Triodes (Correspondence)	Proceedings of the I.R.E. April 1958	Feasible device techniques are available for the fabrication of *n-p-n* diffused base devices.	D. M. Unger A. Avakian
A Solid State Amplifying Fluorescent Screen	RCA Review March 1958	A thin solid-state panel has been developed which, with x-ray intensities, produces a high contrast image.	B. Kazan

CHARACTERISTICS CHART of NEW TRANSISTORS

MANUFACTURERS (In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AMP— Amperex Electronic Corp.
BEN— Bendix Aviation Corp.
BOG— Bogue Electric Mfg. Co.
BTHB— British Thomson-Houston Export Co., Ltd.
CBS— CBS-Hytron
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
EEVB— English Electric Valve Co., Ltd.
ESEB— Edison Swan Electric Co., Ltd.
FTHF— French Thomson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HUG— Hughes Aircraft Co.
HIVB— Hivac Ltd.
IND— Industro Transistor Corp.
LCTF— Laboratoire Central de Telecommunications
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NPC— Nucleonics Products Co.
PHI— Philco Corp., Lansdale Tube Co.
PYEB— Pye Industrial Electronics, Ltd.
RAY— Raytheon Mfg. Co.
RCA— Radio Corp. of America, Semiconductor Div.
SIE— Siemens & Halske Aktiengesellschaft
SPE— Sperry Gyroscope Co.
SPR— Sprague Electric Co.
SYL— Sylvania Electric Products Inc.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Draht-werke
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments
TUN— Tung-Sol Electric, Inc.
TOK— Tokyo Tsushin Kogyo, Ltd.
WEC— Western Electric Co., Inc.
WEST— Westinghouse Electric Corp.

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. (See code at end of chart)
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
2N194A	6	NPN	Ge	50	1000	—	20	3.0	h_{fe}(I_c-1ma)	—	SYL
2N235B	3	PNP	Ge	—	2.2	40	—	—	h_{fe}(I_c-.5A)	60	BEN
2N236B	3	PNP	Ge	—	2.0	40	—	—	h_{fe}(I_c-.75A)	60	BEN
2N301 (P)	3	PNP(A)	Ge	11W	1.0	40	40	—	h_{FE}(I_c-1A)	70	RCA, SYL
2N301A (P)	3	PNP(A)	Ge	11W	1.0	60	60	—	h_{FE}(I_c-1A)	70	RCA, SYL
2N306 (P)	1	NPN	Ge	50	1000	20	15	1.2	h_{fe}(I_c-1ma)	75	SYL
2N373	4	PNP(D)	Ge	80	750	25	—	30	h_{fe}(I_c-1ma)	60	RCA
2N374	4	PNP(D)	Ge	80	750	25	—	30	h_{fe}(I_c-1ma)	60	RCA
2N378 (P)	3	PNP(A)	Ge	—	1.2	40	—	—	h_{FE}(I_c-2A)	30	TUN
2N379 (P)	3	PNP(A)	Ge	—	1.2	80	—	—	h_{FE}(I_c-2A)	30	TUN
2N380 (P)	3	PNP(A)	Ge	—	1.2	60	—	—	h_{FE}(I_c-2A)	50	TUN
2N420A	3	PNP	Ge	—	2.2	70	—	—	h_{FE}(I_c-4A)	50	BEN
2N459 (P)	3	PNP(A)	Ge	—	1.2	105	—	—	h_{FE}(I_c-2A)	30	TUN
2N506	1	PNP	Ge	50	1200	40	—	1.2	h_{FE}(I_c-10ma)	37.5	SYL
2N507	1	NPN	Ge	50	1200	40	—	1.2	h_{FE}(I_c-10ma)	37.5	SYL
2N515	1, 4	NPN	Ge	50	1000	—	18	3.0	I-F PG @ 455kc	25	SYL
2N516	1, 4	NPN	Ge	50	1000	—	18	3.0	I-F PG @ 455kc	27	SYL
2N517	1, 4	NPN	Ge	50	1000	—	18	3.0	I-F PG @ 455kc	28.5	SYL
2N553	3	A	Ge	35W	2.0	80	40	$f_{\alpha e}$-30kc	h_{FE}(I_c-.5A)	55	DEL
2N576A	5	NPN	Ge	200	375	40	20	5.0	h_{FE}(I_c-400ma)	30	SYL

NOTATIONS

Under Use

1—Low power α-f equal to or less than 50 *mw*
2—Medium power α-f > 50 *mw* and equal to or less than 500 *mw*
3—Power > 500 *mw*
4—r-f/i-f
5—Switching & Computer

Under Type and Type No.

A—Alloyed
D—Diffused or Drift
G—Grown
H—Hook Collector
M—Microalloy
O—Other
P—Previously released with new specs
S—Surface Barrier
UNI—Unijunction Transistor
Y—Symmetrical

Under f_{ab}

* Maximum Frequency
# Figure of Merit

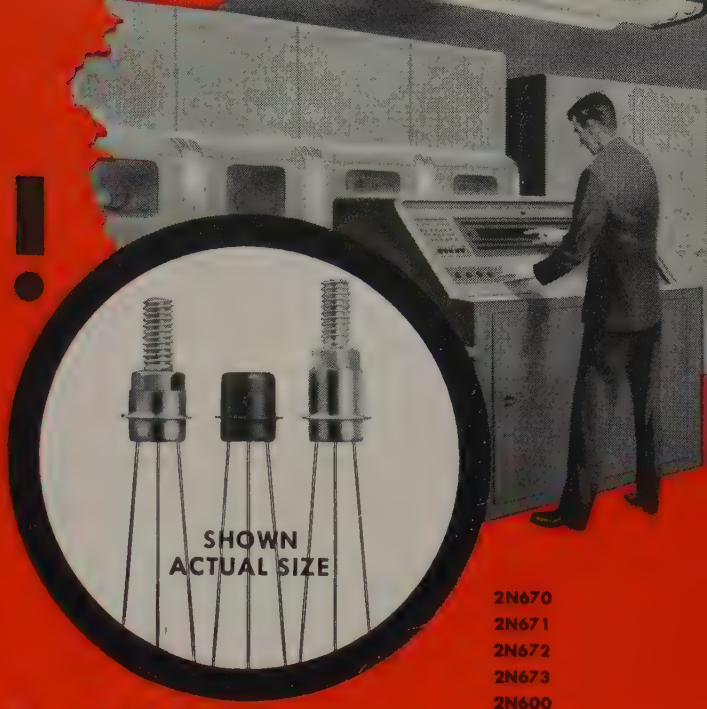
Other

6—Phototransistors
7—@ 70° C
8—I_{CBO} (V_{CB} = −20) = −25 μA
9—Rise time −2 μsec
10—Rise time −3.5 μsec
11—Rise time −6.5 μsec
12—Frequency for f_{ab}=1

NEW FROM PHILCO!

Medium and High Power Transistors

FOR COMPUTERS AND INDUSTRIAL CONTROL SYSTEMS



2N670
2N671
2N672
2N673
2N600
2N601

TYPE	$V_{CE\ MAX}$ (Volts)	$I_{C\ MAX}$ (Amps)	P_{MAX} (Watts)	$f_{\alpha b}$ (mc)
2N670	40	2	0.3	0.65
2N671	40	2	1	0.65
2N672	25	2	0.3	1
2N673	20	2	1	1
2N600	20	0.4	0.75 (1.0 peak)	5 MIN.
2N601	20	0.4	0.75 (1.0 peak)	12 MIN.

Announcing Philco's newest family of PNP germanium alloy junction, high current switching transistors specifically designed for industrial relay driving and pulse amplifier applications and for computer core driver circuits. These transistors feature current ratings to 2 amps, voltage ratings to 40v and alpha cutoff frequencies to 12 mc.

- The 2N670 and 2N671 with 2 amps max. collector current, continuous max. power dissipation up to 1 watt, plus controlled current gain, input drive voltage and saturation resistance at 1 amp are particularly useful in "ON-OFF" industrial control systems.
- Types 2N672 and 2N673 featuring a maximum 0.5 microsecond, one-half ampere rise time are intended for pulse amplifier and tape and drum writer applications.
- The 2N600 and the 2N601 are high speed power switches specially designed for core driving applications. They feature power dissipation up to 1 watt, current ratings of 400 ma and controlled minimum alpha cutoff frequencies of 5 and 12 mcs.

Each of these transistors is housed in Philco's exclusive cold welded, all-copper, hermetically sealed package on JETEC TO-9 base. Positive heat sinking is obtained by tieing a transistor element to the copper case. Types 2N671, 2N673, 2N600 and 2N601 are designed with threaded stud and hexagonal shoulder assembly. All of these transistors are available in production quantities.

For further information circle No. 17 on Reader Service Card

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PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

TRANSISTOR CENTER U.S.A.

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. (See code at end of chart)
				P_c (mw)	DERATING °C W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
2N586	2, 5	PNP(A)	Ge	250	—	45	—	—	h_{fe}(I_c-250ma)	60	RCA
2N591	1	PNP(A)	Ge	50	340	—	32	.70	h_{fe}(I_c-2ma)	70	RCA
2N614	2	PNP	Ge	150	400	25	—	3.0	PG	30	WEST
2N615	2	PNP	Ge	150	400	25	—	5.0	PG	35	WEST
2N616	2	PNP	Ge	150	400	25	—	9.0	PG	25	WEST
2N617	2	PNP	Ge	150	400	25	—	9.0	PG	30	WEST
2N624	2	PNP	Ge	100	750	30	20	—	PG @ 12.5mc	25	SYL
2N625	5	NPN	Ge	500	130	40	30	t_r = 0.4 μsec	h_{FE}(I_c-500ma)	30	SYL
2N626	3, 5	NPN	Ge-Si	10W	6.5°C./W	30	30	.1	@ I_c = 1A	24000	ARA
2N631	—	PNP(A)	Ge	160	360	25	20	1.2	h_{fe}(I_c-10ma)	150	RAY
2N632	—	PNP(A)	Ge	160	360	30	24	1.0	h_{fe}(I_c-10ma)	100	RAY
2N633	—	PNP(A)	Ge	160	360	35	30	.80	h_{fe}(I_c-10ma)	60	RAY
2N650	2	PNP(A)	Ge	200	350	45	25	2.0	h_{fe}(I_c-1ma)	40	MOT
2N651	2	PNP(A)	Ge	200	350	45	25	2.5	h_{fe}(I_c-1ma)	75	MOT
2N652	2	PNP(A)	Ge	200	350	45	25	3.0	h_{fe}(I_c-1ma)	160	MOT
2N653	2	PNP(A)	Ge	200	350	30	15	2.0	h_{fe}(I_c-1ma)	40	MOT
2N654	2	PNP(A)	Ge	200	350	30	15	2.5	h_{fe}(I_c-1ma)	75	MOT
2N655	2	PNP(A)	Ge	200	350	30	15	3.0	h_{fe}(I_c-1ma)	160	MOT
2N658	—	PNP(A)	Ge	170	350	25	16	5.0	h_{FE}(I_B-1ma)	50	RAY
2N659	—	PNP(A)	Ge	170	350	25	14	10	h_{FE}(I_B-1ma)	70	RAY
2N660	—	PNP(A)	Ge	170	350	25	11	15	h_{FE}(I_B-1ma)	90	RAY
2N661	—	PNP(A)	Ge	170	350	25	9	20	h_{FE}(I_B-1ma)	120	RAY
2N662	—	PNP(A)	Ge	170	350	25	11	8.0	h_{FE}(I_B-1ma)	60	RAY
2N669	3	PNP(A)	Ge	40W	1.0	40	30	.4	h_{fe}(I_c-.5A)	100	MOT
2N670	2, 5	A	Ge	300	—	40	40	0.650	h_{fe}(1.5V, 1A)	100	PHI
2N671	3, 5	A	Ge	1000	—	40	40	0.650	h_{FE}(1.5V, 1A)	100	PHI
2N672	2, 5	A	Ge	300	—	25	25	0.650	—	—	PHI
2N676	3, 5	PNP	Ge-Si	10W	6.5	30	30	.1	h_{fe}(I_c-1A)	24000	ARA
2N677	3, 5	PNP	Ge	—	1.5	30	—	—	h_{FE}(I_c-10A)	40	BEN
2N677A	3, 5	PNP	Ge	—	1.5	40	—	—	h_{FE}(I_c-10A)	40	BEN
2N677B	3, 5	PNP	Ge	—	1.5	70	—	—	h_{FE}(I_c-10A)	40	BEN
2N677C	3, 5	PNP	Ge	—	1.5	80	—	—	h_{FE}(I_c-10A)	40	BEN
2N678	3, 5	PNP	Ge	—	1.5	30	—	—	h_{FE}(I_c-10A)	75	BEN
2N678A	3, 5	PNP	Ge	—	1.5	40	—	—	h_{FE}(I_c-10A)	75	BEN
2N678B	3, 5	PNP	Ge	—	1.5	70	—	—	h_{FE}(I_c-10A)	75	BEN
2N678C	3, 5	PNP	Ge	—	1.5	80	—	—	h_{FE}(I_c-10A)	75	BEN
2N679	5	NPN	Ge	150	400	25	20	3.0	h_{FE}(I_c-30ma)	30	SYL
2N773	3, 5	A	Ge	1000	—	25	25	0.650	—	—	PHI
2N1017	—	PNP(A)	Ge	170	350	30	10	20	h_{FE}(I_B-1ma)	100	ARA
2N1019 (H)	3, 5	PNN	Ge-Si	10W	6.5	30	30	$f_{\alpha e}$ 8kc	α(I_c-1A) (hook coll.)	15000	ARA
2N1020 (H)	3, 5	NPP	Ge-Si	10W	6.5	30	30	$f_{\alpha e}$ 8kc	α(I_c-1A) (hook coll.)	15000	ARA
2N1024	2, 5	PNP	Si	150	830	15	15	1.0	h_{fe}(I_e-1ma)	9 min.	SPE
2N1025	2, 5	PNP	Si	150	830	35	35	1.0	h_{fe}(I_e-1ma)	14	SPE
2N1026	2, 5	PNP	Si	150	830	35	35	2.0	h_{fe}(I_e-1ma)	36	SPE
2N1027	2, 5	PNP	Si	150	830	15	15	4.0	h_{fe}(I_e-1ma)	18	SPE
2N1028	2, 5	PNP	Si	150	830	10	10	1.8	h_{fe}(I_e-1ma) (4mc)	9	SPE

NOTATIONS

Under Use

1—Low power a-f equal to or less than 50 mw
2—Medium power a-f > 50 mw and equal to or less than 500 mw
3—Power > 500 mw
4—r-f/i-f
5—Switching & Computer

Under Type and Type No.

A—Alloyed
D—Diffused or Drift
G—Grown
H—Hook Collector
M—Microalloy
O—Other
P—Previously released with new specs
S—Surface Barrier
UNI—Unijunction Transistor
Y—Symmetrical

Under $f_{\alpha b}$

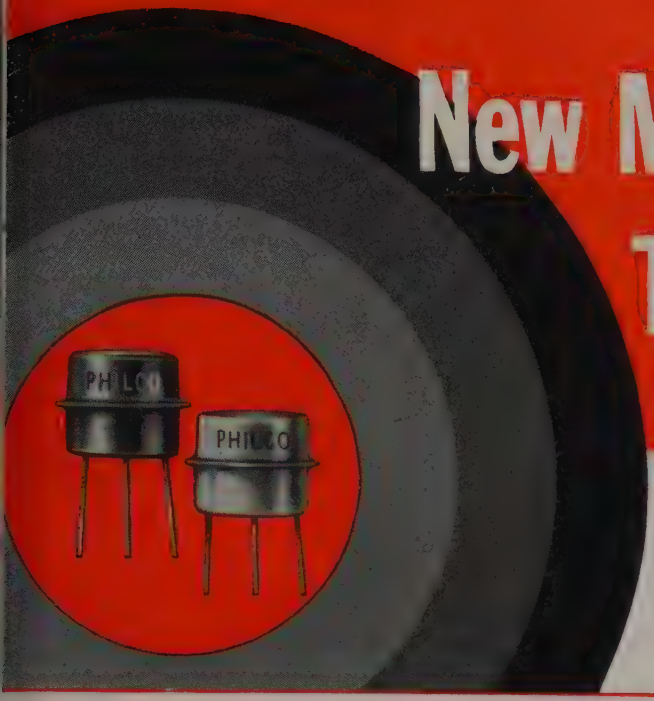
* Maximum Frequency
# Figure of Merit

Other

6—Phototransistors
7—@ 70° C
8—I_{CBO} (V_{CB} = −20) = −25 μA
9—Rise time −2 μsec
10—Rise time −3.5 μsec
11—Rise time −6.5 μsec
12—Frequency for $f_{\alpha b}$ = 1

From PHILCO Transistor Center, U.S.A.

New Medium Frequency Transistor Family!



- High Dissipation: 250 mw at 25°C
- High Current: Max. I_C = −400 ma
- High Temperature: 100°C Max.
- High Voltage: Max. V_{CB} = −30v
- High Frequencies: Min. $f_{\alpha b}$ to 12 mc

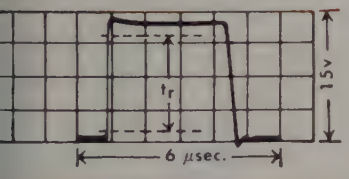
PERFORMANCE DATA

Type	General Performance: Minimum $f_{\alpha b}$	General Performance: Typical h_{FE}	Max. Ratings: I_C	Max. Ratings: V_{CB}	"ON" Switch Performance Max.: V_{CE}	"ON" Switch Performance Max.: V_{BE}
2N597	3 mc	V_{CE} = −1v, I_C = −100 ma 35	400	30	0.2	0.34
2N598	5 mc	V_{CE} = −1v, I_C = −100 ma 90	400	30	0.2	0.34
2N599	12 mc	V_{CE} = −1v, I_C = −100 ma 105	400	30	0.2	0.34

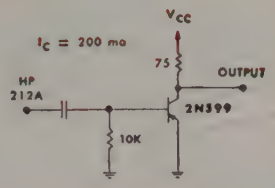
Total Device Dissipation at 25°C = 250 mw

TYPICAL RISE TIME CIRCUIT

2N599

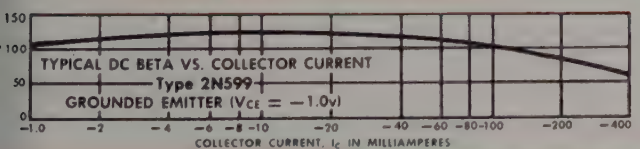


SWITCHING TIMES



TEST CIRCUIT

TYPICAL DC BETA VS. COLLECTOR CURRENT



Announcing a new Philco family of PNP germanium alloy junction transistors (In TO-9 [JETEC 30-type] housing). These transistors feature a unique, patented, cold-welded *copper* housing and internal construction that result in lower junction temperatures at normal operating power levels. Design of the 2N597, 2N598 and 2N599 insures improved life and reliability at temperatures as high as 100°C. Available in production quantities.

The high beta of these transistors at high currents makes them particularly applicable to medium speed flip-flops, logic gates, drum writers and core-driver circuits. The 30v collector rating provides the high level logic swings required in many data processing equipments. At 200 ma of collector current typical rise time for the illustrated circuit is 0.05 μsec.

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PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. (See code at end of chart)
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
B113	3, 5	PNP	Ge	—	2.0	80	—	—	$h_{FE}(I_c$-.4A)	40	BEN
B177	3, 5	PNP	Ge	—	2.2	30	—	—	$h_{fe}(I_c$-.5A)	150	BEN
B178	3, 5	PNP	Ge	—	2.2	30	—	—	$h_{fe}(I_c$-.5A)	40	BEN
B179	3, 5	PNP	Ge	—	2.2	40	—	—	$h_{fe}(I_c$-.5A)	25	BEN
GA53213	2	PNP(A)	Ge	120	500	30	30	1.4	$h_{FE}(I_E$-1ma)	24	WEC
H3A (P)	3	PNP(A)	Ge	5000	14	60	60	—	$h_{FE}(I_B$-250μa)	19	MIN
H4A (P)	3	PNP(A)	Ge	5000	14	60	60	—	$h_{FE}(I_B$-250μa)	30	MIN
H45	3	PNP(A)	Ge	32W	2.2	80	80	.170	$h_{FE}(I_c$-2A)	20	MIN
LT11	3	PNP	Ge	—	3.0	80	—	.18	$h_{FE}(I_c$-.5A)	36	CBS
LT12	3	PNP	Ge	—	3.0	100	—	.18	$h_{FE}(I_c$-.5A)	36	CBS
LT13	3	PNP	Ge	—	3.0	120	—	.18	$h_{FE}(I_c$-.5A)	36	CBS
LT14	3	PNP	Ge	—	3.0	150	—	.18	$h_{FE}(I_c$-.5A)	36	CBS
LT51	3	PNP	Ge	—	3.0	60	—	—	h_{FE}	30	CBS
TK20A (Y)	2	PNP(A)	Ge	100	250	30	—	6.3	$h_{fe}(I_e$-1ma)	43	STCB
TK21A (Y)	2	PNP(A)	Ge	100	250	30	—	2.0	$h_{fe}(I_e$-20ma)	23	STCB
TK24A (Y)	2	PNP(A)	Ge	100	250	30	—	2.5	$h_{fe}(I_e$-40ma)	32	STCB
TK25A (Y)	2	PNP(A)	Ge	100	250	20	—	10	$h_{fe}(I_e$-1ma)	63	STCB
TK26A (Y)	2	PNP(A)	Ge	100	250	30	—	2.0	$h_{fe}(I_e$-20ma)	23	STCB
TK27A (Y)	2	PNP(A)	Ge	100	250	30	—	2.5	$h_{fe}(I_e$-40ma)	32	STCB
TR34	2	PNP(A)	Ge	150	—	—	20	—	$h_{fe}(I_c$-1ma)	15	IND
TR721	2	PNP(A)	Ge	150	—	—	20	—	$h_{fe}(I_c$-1ma)	45	IND
TS7 (Y)	2	PNP(A)	Ge	70	500	20	—	4.0	$h_{fe}(I_e$-1ma)	35	STCB
TS8 (Y)	2	PNP(A)	Ge	70	500	10	—	8.5	$h_{fe}(I_e$-1ma)	65	STCB
TS9	2	PNP(A)	Ge	130	270	56	—	.60	$h_{fe}(I_e$-10ma)	70	STCB
TS13	2	PNP(A)	Ge	70	500	30	—	.60	$h_{fe}(I_e$-1ma)	52	STCB
TS14	2	PNP(A)	Ge	70	500	30	—	.50	$h_{fe}(I_e$-1ma)	32	STCB
TS15	2	PNP(A)	Ge	70	500	65	—	.50	$h_{fe}(I_e$-1ma)	35	STCB
XA101	2	PNP(A)	Ge	90	330	20	16	5.0	$h_{fe}(I_c$-1ma)	35	ESEB
XA102	2	PNP(A)	Ge	90	330	20	16	8.0	$h_{fe}(I_c$-1ma)	60	ESEB
XB102	2	PNP(A)	Ge	90	330	35	16	—	$h_{fe}(I_c$-1ma)	30	ESEB
XB103	2	PNP(A)	Ge	90	330	35	16	—	$h_{fe}(I_c$-1ma)	66	ESEB
XC101	2	PNP(A)	Ge	166	300	35	16	—	$h_{fe}(I_c$-8ma)	66	ESEB
XS101 (Y)	2, 5	PNP	Ge	150	330	21	—	2.5	$h_{fe}(I_c$-1ma)	20	ESEB

NOTATIONS

Under Use

1—Low power a-f equal to or less than 50 *mw*
2—Medium power a-f > 50 *mw* and equal to or less than 500 *mw*
3—Power > 500 *mw*
4—r-f/i-f
5—Switching & Computer

Under Type and Type No.

A—Alloyed
D—Diffused or Drift
G—Grown
H—Hook Collector
M—Microalloy
O—Other
P—Previously released with new specs
S—Surface Barrier
UNI—Unijunction Transistor
Y—Symmetrical

Under $f_{\alpha b}$

* Maximum Frequency
# Figure of Merit

Other

6—Phototransistors
7—@ 70° C
8—I_{CBO} (V_{CB}=—20) =—25 μA
9—Rise time —2 μsec
10—Rise time —3.5 μsec
11—Rise time —6.5 μsec
12—Frequency for $f_{\alpha b}$=1

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

General Electric: 2N334, 2N336

Great Eastern Mfg: 2N34, 2N35, 2N68, 2N94, 2N94A, 2N95, 2N101, 2N102, 2N139, 2N141, 2N142, 2N143, 2N144, 2N155, 2N168A, 2N169A, 2N176, 2N193, 2N194, 2N211, 2N212, 2N213, 2N214, 2N214MP, 2N216, 2N217, 2N228, 2N229, 2N233, 2N233A, 2N235A, 2N241A, 2N242, 2N247, 2N250, 2N255, 2N256, 2N257, 2N270, 2N292, 2N296, 2N301, 2N301A, 2N306, 2N307, 2N312, 2N321, 2N325, 2N326, 2N350, 2N351, 2N356, 2N357, 2N358, 2N370, 2N371, 2N372, 2N377, 2N383, 2N384, 2N385, 2N388, 2N399, 2N401, 2N404, 2N406, 2N408, 2N409, 2N410, 2N412, 2N419, 2N420, 2N515, 2N516, 2N517, 2N544, 2N556, 2N557, 2N558, 2N576, 2N587

Industro: 2N413, 2N413A, 2N414, 2N414A

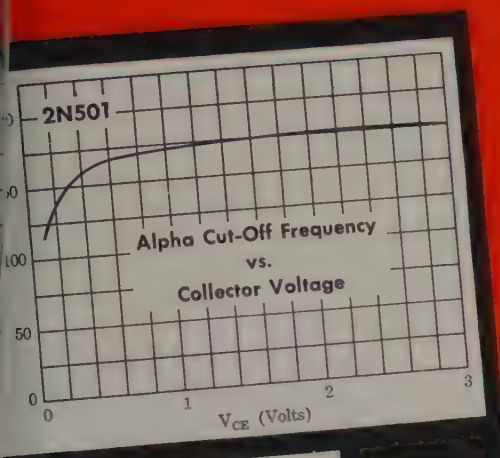
Motorola: 2N425, 2N426, 2N427, 2N428, 2N464, 2N465, 2N466, 2N467

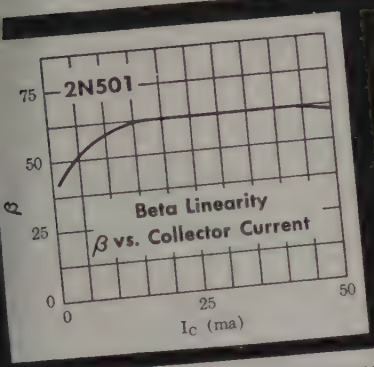
RCA: 2N176, 2N351, 2N376

Sprague: 2N299, 2N300, 2N393, 2N499, 2N500, 2N501, 2N502, 2N503, 2N504, T1050

Tung-Sol: 2N242, 2N307, 2N307A, 2N404, 2N413, 2N414, 2N416, 2N417, 2N578, 2N579, 2N580, 2N581, 2N582

VHF Transistors! First From PHILCO





New family of Micro Alloy Diffused-base Transistors (MADT)*

- Rise, Storage, Fall Time in Low mμsec Range
- High Oscillator efficiency at 200 mcs
- Amplifier gains of 10 db at 200 mcs

MADT FAMILY APPLICATIONS DATA

TYPE*	fmax	Power Gain	Oscillator Efficiency	Class of Use
2N499	250 mcs (min)	10 db at 100 mcs	25% at 100 mcs (min)	oscillator and amplifier to 100 mcs
2N500			25% at 200 mcs (min)	oscillator to 400 mcs
2N501	Ultra high-speed switch typical $t_r = 12$ mμsec; (18 max.); $t_s = 7$ mμsec; (12 max.); $t_f = 4$ mμsec; (10 max.). In circuit with current gain of 10 and voltage turnoff.			
2N502†	500 mcs	10 db at 200 mcs		amplifier to 250 mcs
2N503†		11 db at 100 mcs(min.		amplifier to 100 mcs
2N504	50 mcs	46 db at 455 KC		high gain IF amplifier

*Available in voltage ratings up to 35V.
†In JETEC TO-9 Case (widely known as JETEC 30 Case).

Here is a major breakthrough in the frequency barrier . . . a new family of *field-flow* Micro Alloy Diffused-base Transistors. Philco MADT's extend the range of high gain, high frequency amplifiers; high speed computers; high gain, wideband amplifiers and other critical high frequency circuitry.

MADT's are available to various voltage and frequency specifications for design of high performance transistorized equipment through the entire VHF and part of the UHF spectrum. These transistors range in f_{max} from 250 mc to as high as 1000 mc. MADT gains are typically 10 db at 200 mc and greater than 16 db at 100 mc. A low cost general purpose unit is available which will deliver typically 18 db at 50 mc and 32 db at 10 mc.

Make Philco your prime source of information for high frequency transistor applications.

Write to Lansdale Tube Company, Division of Philco Corporation, Lansdale, Pa., Dept. C-958

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with single diffused silicon junction

Challenging performance . . . to exacting requirements

For your successful application, U. S. Semcor has achieved outstanding performance through positive mechanical stability—vital to electrical stability—and reliability. Exclusive new color code follows EIA sequence for quick visual PIV reference. Also featured is single construction head that eliminates solder seals for higher forward conductance.

PHYSICAL CHARACTERISTICS

- Single Diffused Junction
- Non-position Sensitive
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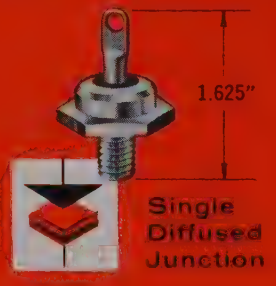
- Welded Hermetic Seal
- Aluminum Heat Sink

LOW PROFILE

Overall height is only 1.625", with smaller encasement and weight just one-fifth that of comparable units.

ELECTRICAL CHARACTERISTICS

- High PIV - 50 to 600 Volts
- Excellent Forward Conductance 25 amps at 1 Volt
- Low 1 ma Saturation Current at rated PIV



Provides matched coefficients of expansion of internal lead wire and diode case, prohibits separation even under extreme shock.

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PATENT REVIEW

[*Continued from page 43*]

October 25, 1949

2,485,589 Selenium Rectifier a Photocell;—F. Gray; Assignee: I ternational Standard Electric Cor One includes in and distribut throughout the selenium layer powdered thermosetting synthe resin.

2,485,593 Rectifier and Method Making the Same;—L. B. Haig Assignee: Federal Telephone a Radio Corp.; A rectifier cell asse bly.

November 15, 1949

2,488,369 Selenium Rectifier;—W. Blackburn; Assignee: Westinghou Electric Corp.; The method of form ing a blocking layer on seleniu which comprises producing there a layer of cadmium sulphide.

November 29, 1949

2,489,767 Rectifier;—P. H. Fennem A. J. van den Hoogenhoff; Assignee The Hartford National Bank an Trust Company; A rectifier assembl with unperforated rectifier element

December 6, 1949

2,490,435 Electrical Rectifier Con struction;—L. K. Heddling; As signee: The Union Switch and Signa Company; An asymmetric rectifie stack.

January 3, 1950

2,493,241 Dry Plate Selenium Recti fier;—S. S. Fry; Assignee: Fanstee Metallurgical Corp.; Production of blocking layer device by the actio of hot cyanogen gas upon the sele nium layer.

2,493,643 Metal Rectifier of th Selenium Type;—E. A. Richards Assignee: International Standar Electric Corp.; A rectifier elemen assembly.

January 31, 1950

2,495,716 Rectifier;—J. M. Girard Assignee: International Standar Electric Corp.; The counter-elec trode has a pointed portion whic penetrates an insulating membran and makes point contact with th selenium layer.

February 7, 1950

2,496,346 Semiconductive Resistanc

Provided With Metal Contact;—P. W. Haayman, H. Bruining; Assignee: The Hartford National Bank and Trust Co.; An electrical resistance device made of sintered magnesia containing about 3% of particles of reduced titanium oxide.

2,496,432 Selenium Rectifier;—W. E. Blackburn; Assignee: Westinghouse Electric Corp.; A circuit element comprising a base plate having a selenium layer, a layer of magnesium, aluminum, or beryllium alone or in combination, and a cadmium containing counter electrode.

2,496,692 Selenium Rectifier;—W. E. Blackburn; Assignee: Westinghouse Electric Corp.; A rectifier comprising a barrier layer between selenium surfaced with cadmium sulphide and an alloy containing cadmium, tin, and gallium.

February 14, 1950

2,497,649 Process of Electroforming Selenium Rectifiers;—R. D. Amsden; Assignee: General Electric Company; A method of improving the rectifying characteristics of a selenium cell by conducting therethrough electric pulsation having a polarity opposing the blocking characteristic of said cell.

2,497,770 Transistor-Microphone;—R. L. Hanson; Assignee: Bell Telephone Laboratories; An electromechanical transducer comprising a vibration responsive membrane, two electrodes, and a block of semiconductor material supported between and engaged by the electrodes.

February 21, 1950

2,498,240 Selenium Rectifier;—W. E. Blackburn; Assignee: Westinghouse Electric Corp.; An electrical circuit element comprising an interface between selenium surfaced with cadmium sulphide and an aggregate consisting of cadmium and an alkali metal.

February 28, 1950

2,498,666 Rectifier Unit;—C. A. Escoffery, W. H. Hawk; Assignee: Federal Telephone and Radio Corp.; A rectifier comprising a metal rod base element carrying a coating of semiconductive selenium. The unit is formed in a hermetically sealed cartridge.

2,498,714 Selenium Rectifier;—A. M. Searle; Assignee: International Standard Electric Corp.; A selenium rectifier element that comprises a perforate ceramic supporting member.

2,498,890 Rectifier Unit;—C. A.

u. s. semcor temperature compensated

REFERENCE ELEMENT

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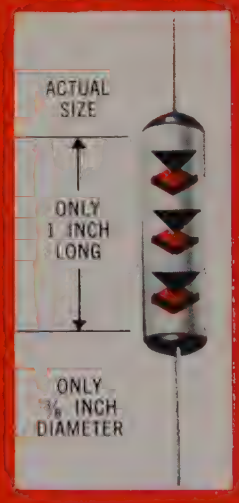

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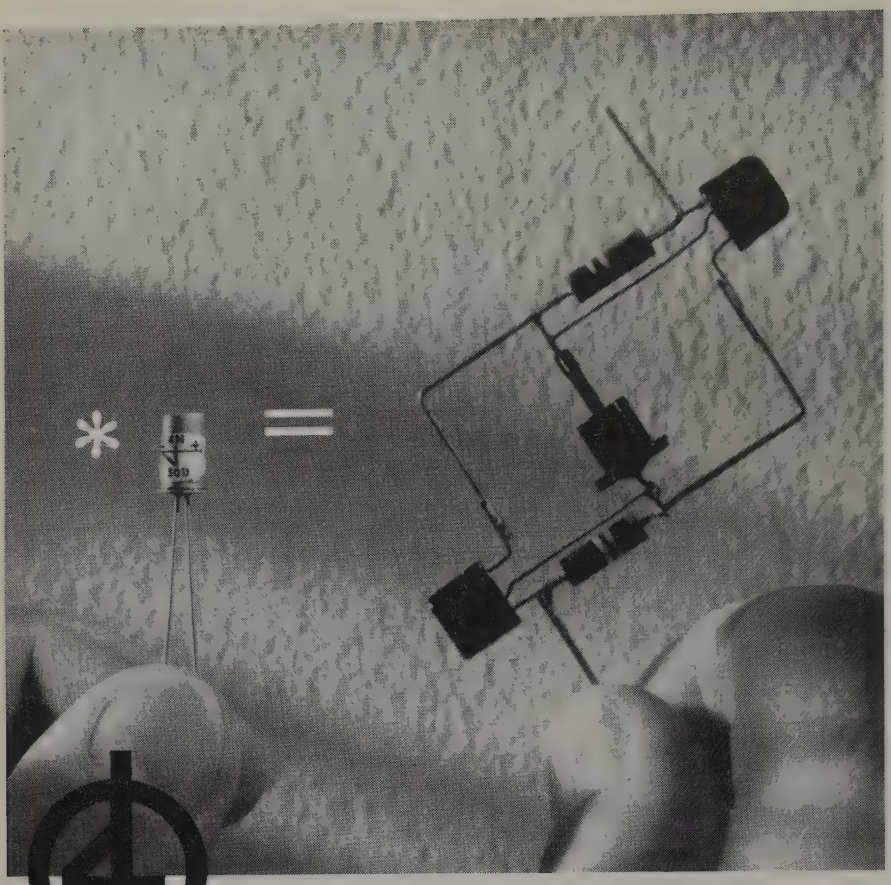
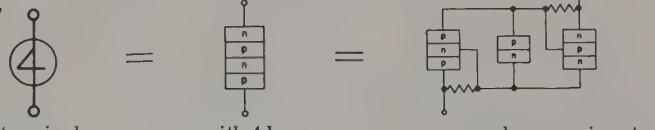


SHOCKLEY 4-LAYER TRANSISTOR DIODE* SIMPLIFIES SWITCHING CIRCUITRY FOR COMPUTERS, TELEPHONY, CONTROL

HERE'S HOW



2-terminal switching diode ... with 4 layers, alternate n and p type ... can replace conjugate structure of 5 components

RANGE OF CHARACTERISTICS

V_b (breakdown voltage)	20-100v	R_h ("on" resistance)	< 20 ohms (from 1—3 amps., voltage < 1 volt plus 0.2 to 1.5 ohms times current)
I_b (breakdown current)	< 500 μa	Dissipation	≈ 100 mw
V_h (holding voltage)	< 2V	Time to close	< 0.1 μsec
I_h (holding current)	< 50 ma	Time to open	< 0.2 μsec

STANDARD TYPES AVAILABLE FOR DELIVERY NOW

No.	V_b Volts	I_b μa	V_h Volts	I_h ma	R_h ohms
4N20D	20±5	< 500	< 2	< 50	< 10
4N30D	30±5	< 500	< 2	< 50	< 10
4N40D	40±5	< 500	< 2	< 50	< 10
4N50D	50±5	< 500	< 2	< 50	< 10

ENGINEERING DATA AND ASSISTANCE

Our engineering staff, under the direction of Dr. William Shockley, will undertake circuit problems in typical applications such as: sawtooth oscillators, pulse generators, bistable circuits, ring counters and various switching functions. Special types of transistor diodes are being developed to individual specifications. Technical information on request. Write to Dept. 1A-7I8.

Invented at Bell Telephone Laboratories.

Shockley Transistor Corporation

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Kotterman; Assignee: Kotron Rectifier Corp.; A metal plate rectifier assembly.

March 28, 1950

2,501,331 Liquid Cooled Rectifier Assembly;—C. C. Hein; Assignee: Westinghouse Electric Corp.; A plate type rectifier assembly adapted to draw current from an n-phase alternating source and to supply current to a direct current circuit of n units.

2,501,798 Blocking-Layer Cell;—W. C. van Geel, A. J. Dekker; Assignee: The Hartford National Bank and Trust Company; The manufacture of a blocking-layer cell by electrophoretically depositing a homogeneous selenium blocking layer on an electrode of the cell.

April 4, 1950

2,502,479 Semiconductor Amplifier;—G. L. Pearson, W. Shockley; Assignee: Bell Telephone Laboratories; A translating device comprising a filament of semiconductive material and means for making three connections.

2,502,488 Semiconductor Amplifier;—W. Shockley; Assignee: Bell Telephone Laboratories; A translating device comprising a body of semiconductive material having zones of opposite conductivity type separated by a barrier, an ohmic connection to each zone remote from the barrier, and a rectifying contact on one zone closely adjacent to the barrier.

2,502,540 Method of Manufacturing Blocking Layer Cells of the Selenium Type;—J. J. van Amstel; Assignee: The Hartford National Bank and Trust Company; Steps in the manufacturing of a blocking layer selenium rectifier cell.

2,502,729 Rectifying Installation;—H. A. Klinkhamer; Assignee: The Hartford National Bank and Trust Company; A system for maintaining a battery connected to a load in a charged condition.

April 11, 1950

2,503,429 Metallic Casing for Electrical Units;—A. W. Ziegler; Assignee: Bell Telephone Laboratories; A solder sealed metallic casing for an electric translating device.

2,503,837 Electrical Translating Device;—R. S. Ohl; Assignee: Bell Telephone Laboratories; Construction of the device including the rectifying element.

April 18, 1950

2,504,226 Devices Which Have Se-

lenium as Constituent Parts Thereof;—D. W. Rau, A. H. Bruemmer; A method of enhancing the ability of selenium to resist current flow in one direction without appreciably increasing its resistance to current flow in the other direction.

April 18, 1950

2,504,627 Electrical Device With Germanium Alloys;—S. Benzer; Assignee: Purdue Research Foundation; A semiconducting body of nitrogen-germanium alloy having *p*-type and *n*-type regions has a point contact conductor placed in a region that causes the resistance of the device to be light-sensitive.

2,504,628 Electrical Devices With Germanium Alloys;—S. Benzer; Assignee: Purdue Research Foundation; A light-sensitive, point-contact germanium device consisting of *n*-type and *p*-type germanium, can regulate the saturation current between the semiconductor and the point contact.

April 25, 1950

2,504,965 Electrical Bridge Network;—V. C. Davis; An electrical bridge circuit containing many asymmetrical conductors.

2,505,633 Alloys of Germanium and Method of Making Same;—R. M. Whaley; Assignee: Purdue Research Foundation; Germanium 99% pure is alloyed with nitrogen at pressures between 2 mm and 760 mm Hg and at temperatures between 1000°C. and 1100°C.

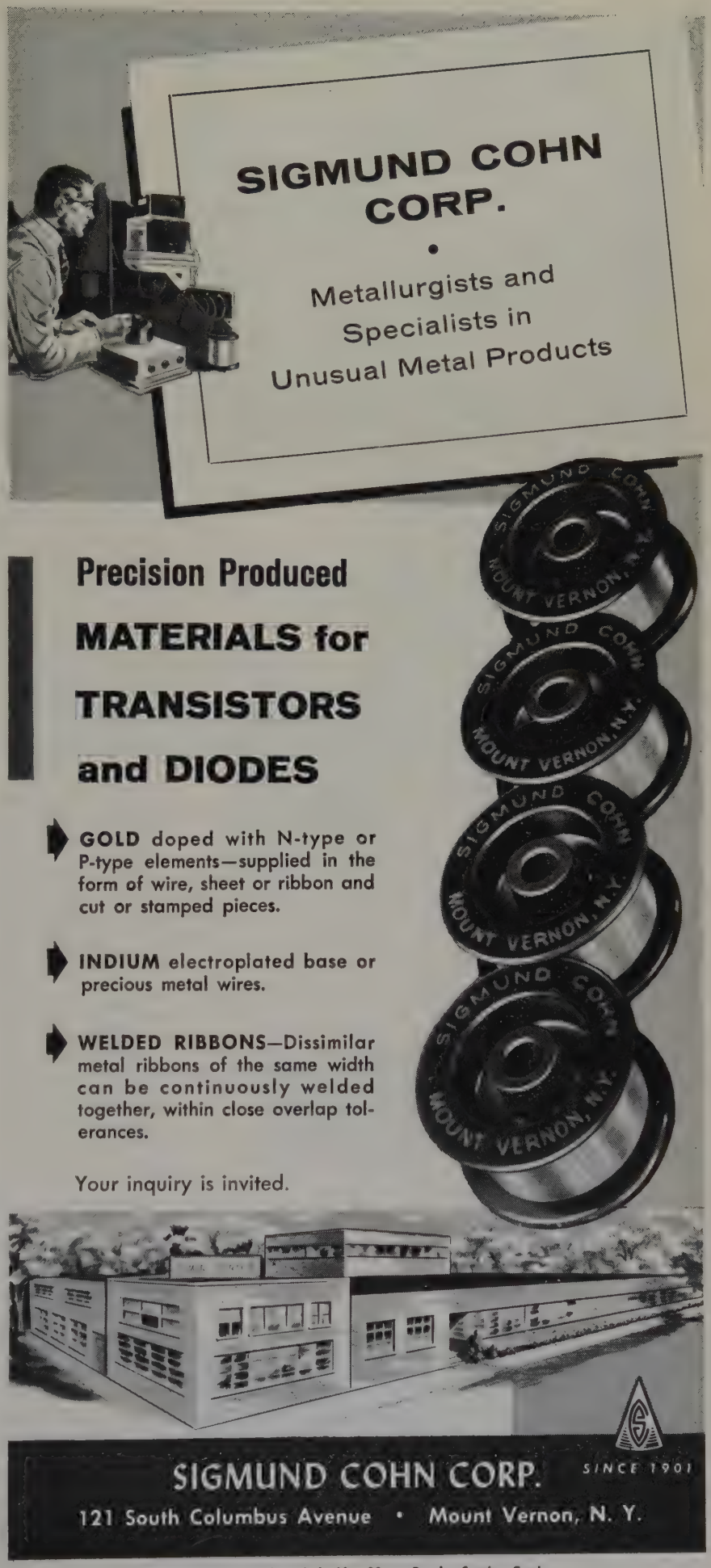
May 2, 1950

2,505,936 Temperature Compensated Conductivity Cell Electrode;—E. R. Behn; Assignee: Control Instrument Company, Inc.; Unit consists of a thermally and electrically conductive shell and a semiconductor with a negative temperature coefficient of resistance.

2,506,067 Plug-In Electrical Unit;—C. E. Cohn; Assignee: None;Electrical elements within an insulating cup, said elements comprising a dry disk rectifier and electrical resistors.

2,506,386 Methyl Germanium Compounds and Methods of Preparing the Same;—E. G. Rochow; Assignee: General Electric Company; Method consists of mixing methyl germanium halide with water, passing hydrogen sulfide through the mixture, and isolating the insoluble methyl germanium sulfide.

[CONTINUED IN NEXT ISSUE]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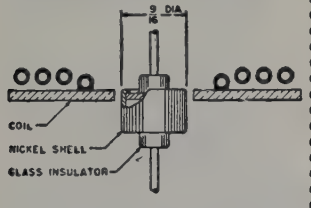
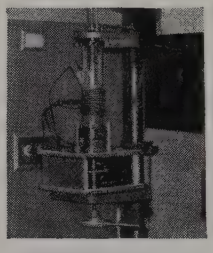
TYPICAL INDUCTION HEATING APPLICATIONS IN THE MANUFACTURE OF TRANSISTORS

SOLDERING TRANSISTOR ASSEMBLIES BY INDUCTION HEATING



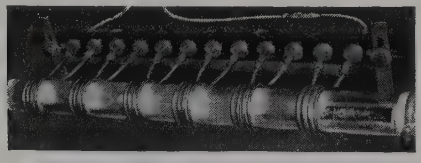
Concentrator-type coil creates high intensity, restricted heating at joint of nickel shell and tinned glass, thus causing solder to flow for permanent seal.

SINGLE CRYSTAL PULLER



General arrangement for pulling single crystals. Induction heating coil is shown surrounding quartz tube containing crucible with molten germanium in suitable atmosphere.

MULTIPLE ZONE REFINING



Induction heating apparatus used in zone refining. The six coils shown provide simultaneous molten zones in the ingot as it passes through the tube containing the protective atmosphere.

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EDITORIAL [*from page 7*]

their companies well by sending greater numbers of their scientific personnel to these gatherings.

Military Applications of Transistors

In a paper presented by J. P. Molnar at the Bell Telephone Transistor Press Conference on June 7th, the importance of the transistor in military applications was indicated. One of the examples discussed was a transistorized helmet radio designed by the U. S. Army Signal Corps Research & Development Labs at Fort Monmouth. Except for the microphone, the entire transmitter and receiver, which weighs only a few ounces, fits inside the helmet. Another illustration quoted showing the importance of the transistor was in the general area of computers used in the control of missiles. In one such application, the computer is contained in the missile itself and rides with it in flight. These are significant illustrations of how transistors pay off in their ability to keep weight and power consumption at a minimum, and point up the tremendous application possibilities of transistors for military use.

A New Service

This issue of SEMICONDUCTOR PRODUCTS includes the first installment of PATENT REVIEW beginning on page 41. The purpose of this department is to provide a complete file of patent information pertaining to semiconductor devices, fabrication techniques and processes, and circuits and applications from 1948 on. At the outset, and until such time as the department catches up with current patents, each item will be necessarily a brief abstract of the patent in question. Subsequently, they will be dealt with in greater detail. In this issue we cover the patents announced in 1948, 1949 up to May 2, 1950. In subsequent issues we will provide approximately the same page space in providing this information. As a final goal we will provide current patent information quarterly. This is another service we embark upon for our readers. We invite comment and criticism.

Conference on Silicon Carbide

A conference on silicon carbide, the new semiconductor, is scheduled at Boston, April 2-3, 1959, under the auspices of the Air Force Cambridge Research Center. A twofold objective characterizes the arrangements for this meeting: (1) to consider the preparation, properties, and applications of the new material; (2) to consolidate efforts on its research and development. The program includes several invited papers from this country and abroad, submitted comprehensive papers (30 minutes), and brief reports on recent developments.

Samuel L. Marshall

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- ► Other Current-Sensitive Devices

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- Model CG-11 Transistorized .05 — 5 amps
- Model CG-12 Transistorized .5 — 30 amps

For further data, write for Bulletin E-1M

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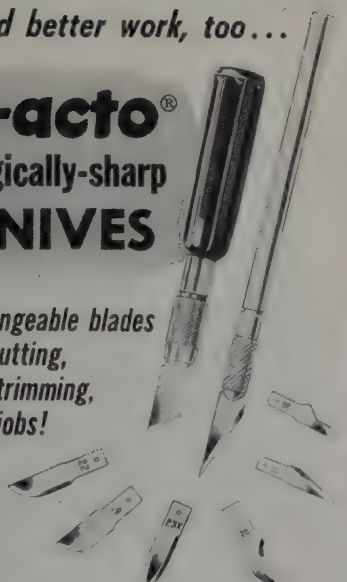

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New Products

Voltage Limiter

Electronic Measurements Co., Inc. announces the development of an instantaneous, all-electronic voltage limiter for use with power supplies. The voltage limiter is used to protect transistors, and other voltage sensitive devices. from damage due to both low- and high-speed voltage excursions. The limiter is adjustable to provide protection at any voltage between 0 and 50 volts, and it will handle power supplies with ratings up to 3 amps.

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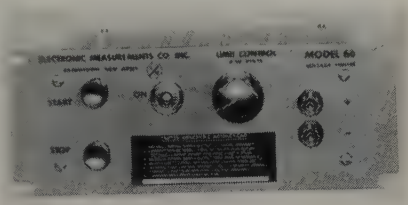


Hall Effect Semiconductor

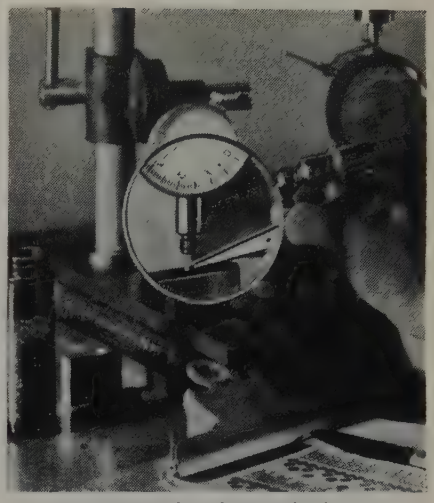
Ohio Semiconductors announces a new semiconductor device based upon the Hall effect. The device is called a Halltron, type HS-51. This particular device utilizes a thin wafer of indium antimonide. Many applications are anticipated in electrical and electronic circuits and in transducers for control circuits, computer functions and instrumentation systems. The output voltage is a function of the product of an input current and an applied magnetic field, and can be used as an inverter of *dc* to *ac*, as a measure of magnetic field, a measure of power, a gyrator, a circulator, a measure of position, and a host of other applications.

Circle 101 on Reader Service Card

Zener Voltage Regulators

U. S. Semiconductor Products Inc. announces a new line of diffused junction, silicon Zener voltage regulators available in voltages ranging from 8.0 to 30 volts, and up to 150 volts on special order. The new devices, which have a double anode configuration, feature low Zener impedance, maxi-

components for
semi-conductors



Inspection by contact.

High Purity Dot Material

ACCURATE SPECIFICATIONS

Weight Specifications:

► **DISCS:**
Where gauge is 2/3 of diameter or less, weight control maintained to ±2%, except where gauge falls below .008".

Size Specifications:

► **DISCS:**
Diameter maintained at ± .0005"; in special cases ± .0002".

► **SPHERES:**
Normal tolerances as follows:
.001" to .010" ± .0002"
.011" to .027" ± .0003"
.028" to .035" ± .0004"
.036" to .045" ± .0006"
Tolerances listed have been exceeded and held to ± .0001".

Our design and production engineers are available for consultation on any problems you may encounter in the realm of semi-conductor alloys. For bulletin write or call today. No obligation, of course.

ACCURATE
SPECIALTIES CO., INC.

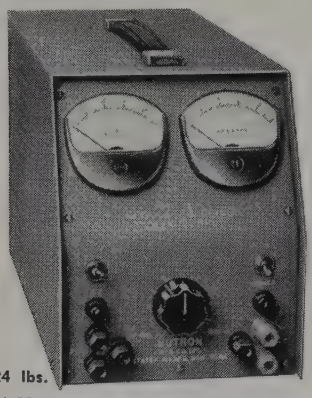
37-13 57th St. • Woodside 77, N. Y.
TWining 9-5757

circle No. 27 on Reader Service Card

ELECTRONICS FOR INDUSTRY
NUTRON
PORTABLE REGULATED POWER SUPPLIES

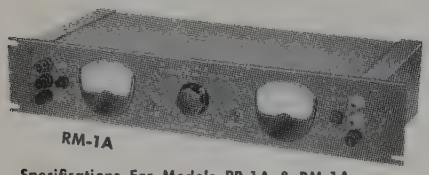
NEW for transistor work

Models PR-1A and RM-1A are especially suited as a power source for most experimental work on transistor circuitry and prototype development of transistor devices. Continuous variable wide voltage range coupled with high current rated over entire voltage range makes these rugged, service free units a basic requirement for every laboratory.



Only 24 lbs.

Model PR-1A
- Hi-Ranges: 0-120V
- High Current 1 Amp. DC
- Regulated DC or AC output
- Extremely low ripple



RM-1A

Specifications For Models PR-1A & RM-1A:
Input: 95-130V, 60 Cycles
DC Output: 0-120V, 0-1 Amp.
AC Output: 0-130V, 0-1 Amp.
Regulation: ± 1% for line 95-130 V
Completely isolated output

Some other applications:
Versatile Production Test Supply
DC or AC motor control
Fine control of saturable reactors
Regulated DC or AC filament supply
Regulated, adjustable line source

Write for Technical Bulletin SC-9

PRICES* ..... **Model PR-1A $165.00**
Model RM-1A $155.00
*With meters, add $30.00
Vernier voltage adjust. available at slight extra cost.

IMMEDIATE DELIVERY!
For Vacuum tube applications request literature on our PR-100 and PR-200 models, rated up to .2 ampere at 300 volts.

NUTRON MANUFACTURING CO., Inc.
67 Monroe Ave., Staten Island 1, N. Y.

circle No. 32 on Reader Service Card

mum power dissipation of 3 watts in free air and 10 watts on a heat sink, and a lower temperature coefficient than can normally be achieved in the usual Zener diode. The anodes are normally matched to within 5%, and units can be selected with anodes matched to within 1%. A single unit can, therefore, be used as a symmetrical clipper.

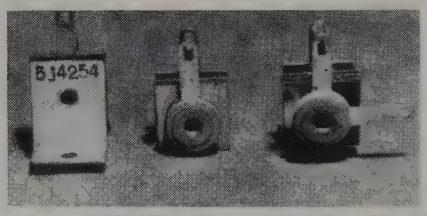
Circle 103 on Reader Service Card

Selenium Rectifiers For Vibrating Cushions

A new, reliable and economical selenium rectifier designed for use in vibrating cushions has been marketed by the Radio Receptor Co.

The rectifier is available with either eyelet construction or with a bracket so that it can be readily spot welded or riveted to the pans at considerable saving in assembly costs. To lower costs further, Radio Receptor has found a means of reducing the number of selenium cells required to do the job.

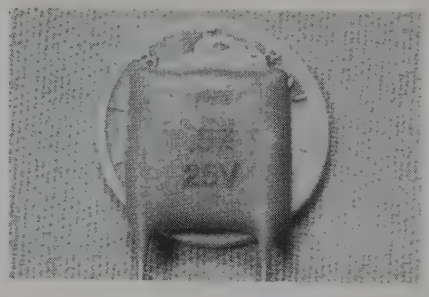
Circle 127 on Reader Service Card



Miniature Ceramic Capacitors

Sprague announces its new layer-built Monolythic ceramic capacitors for transistorized circuitry. Into a small rectangular block ½" x ½" x ⅛" thick, it is possible to pack a capacitance of as much as .75 *mf* at 25 volts *d-c*. The new capacitors are built by spraying alternate layers of ceramic dielectric material and silver electrodes until the desired capacitance is achieved. The resultant capacitors are solid homogeneous blocks. These small capacitors will be of especial interest to designers of military and other minified electronic equipment.

Circle 138 on Reader Service Card



Super-Sub-Miniature transformers
For transistor circuitry in servo-mechanisms, hearing aids, radios, telephones

- High reliability *guaranteed.*
- Higher impedance, with super miniaturization, under *full load.*
- Large quantities used, with transistors, by leading manufacturers.
- Each unit critically inspected.
- Immediate delivery from inventory covering wide range of impedance ratios in sub-miniature and super-sub-miniature sizes.
- Prototypes — Designed or wound and enclosed to specifications. . . . Delivery within two weeks.

For further information and catalog call or write today . . .

Frank Kessler Co., Inc., 41-45 47th St.
L. I. C. 4, N. Y. • Tel.: STillwell 4-0263

circle No. 30 on Reader Service Card

NEW SEMICONDUCTOR DEVICE

Halltron
TYPE HS-51

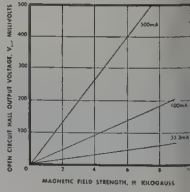
HS-51

The HS-51 HALLTRON is based upon the Hall effect. Its output characteristics are related to the product of the input current and magnetic field, hence are useful in many new applications. The HS-51 HALLTRON is a fully developed production unit utilizing indium antimonide and is designed to work in the customer's magnetic circuit.

Applications of the HS-51 HALLTRON
- DC to AC converters
- Magnetic field measurement
- Computer applications
- Control applications
- Gyrators
- Circulators
- Power meters
- Transducers

Typical Room Temperature Characteristics

Typical open-circuit Hall output voltage of an HS-51 HALLTRON vs. magnetic field strength for various values of control current, Ic.



OHIO SEMICONDUCTORS, INC.
1035 W. THIRD AVENUE, COLUMBUS 8, OHIO

circle No. 31 on Reader Service Card

oxy Resins and Hardeners

Epoxy Products, Inc. announces five sic forms of epoxy to meet the var- is problems of component encapsula- n. They are available as shells and eves in standard sizes which may be achined to special configurations; olded sheets in a variety of thick- sses; casting powders in the form of emixed resin and hardener; pellets ntaining pre-metered compressed sting powder; and liquid resins and rdeners.

Circle 139 on Reader Service Card

urrent Governor

The North Hills Electric Co., Inc., roduces the Model CG-12 Current overnor for constant current. It fea- ires rapid manual or automatic selec- on of the desired current level, high ccuracy and stability, constant current ver a wide voltage range, and a current hich can be electronically switched, ulsed, swept, modulated and pro- rammed. Additional applications in- ude its use as a versatile electronic oad and in the production testing and boratory operation of current sensi- ve devices.

Circle 146 on Reader Service Card

etergent and Solvent

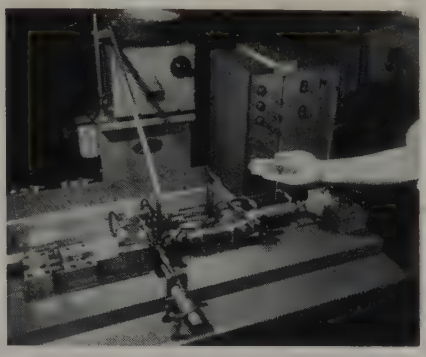
The Narda Ultrasonics Corporation as developed a new water-wash de- rgent and a new degreasing solvent pecially compounded for use in ultra- onic cleaning equipment. The new roducts are known as BLAST 1 for se as an additive to water baths and LAST 2 for use as a degreasing bath s shipped to the consumer. Although esigned to develop maximum efficiency n Narda SonBlasters, BLAST 1 and BLAST 2 will improve the efficiency of any type of ultrasonic cleaning equipment.

Circle 129 on Reader Service Card

Pigtail Welder

An automatic assembly and welding machine for electronic components production is announced by Raytheon Manufacturing Company. The machine turns out precision-welded "pigtail" assemblies at a rate of 3000 per hour. Several machines can be tended by a single operator. Soldered connections have proven unreliable under the temperature extremes encountered in military electronic applications, and fast, sure welding is now a "must."

Circle 134 on Reader Service Card



Tektronix Preamp Power Supply

The Type 127 supplies operating power to any one or combination of two Type 53/54 Plug-In Preamplifiers. Outputs of the plug-in preamplifiers are fed through *dc* coupled differential amplifier stages and cathode followers to provide a push-pull signal at the output. Gain of the unit is one, push-pull. Using single-ended output, gain is one-half. Risetime is 0.018 μsec. Output swing is linear ± 3% over a range of ± 0.3 v. All *dc* voltages supplied to the plug-in units are electronically regulated. The Type 127 can also be used with an oscilloscope for dual-differential and multiple-trace displays.

Circle 132 on Reader Service Card

Chopper

Solid State Electronics Co. announces the Model 50 transistorized chopper (or modulator), a solidly encapsulated unit designed to alternately connect and disconnect a load from a signal source. It may also be used as a demodulator to convert an *ac* signal to *dc*. It is capable of linearly switching or chopping

...when you think of...
TANTALYTIC® CAPACITORS think of
Schweber
IN STOCK—OVER 250 DIFFERENT RATINGS polar and non-polar types
SOLID ELECTROLYTIC
—80°C to +85°C
Available up to 60 volts
Smaller size Higher stability
Lower temperature
Low impedance at higher frequencies
Unlimited shelf life
+125° For high temperature, miniaturized high reliability. Designed for cramped quarters.
+125° Permits maximum flexibility in chassis arrangement in minimum space. High temperature, long life.
KSR
King Size Rectangular
New designs provide up to 40% reduction in weight, and 30% reduction in required space, when compared to other foil tantalum units. Packs a lot in a little space. Costs less per volt-microfarad.
We know you will appreciate a supplier who sells TANTALUM CAPACITORS as a MAIN LINE instead of a side line! Send for our latest specially prepared GE Tantalytic® bulletin.
Schweber ELECTRONICS
60 HERRICKS ROAD — MINEOLA, L. I., N. Y.
PIONEER 6-6520
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PROFESSIONAL GROWTH . . .
STABILITY . . .
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TRANSISTOR & VACUUM TUBE CIRCUIT DESIGN ENGINEERS

PROJECT, SENIOR & STAFF LEVEL

Permanent Positions . . .
Commercial & Military Program

Your talent and ability pay off at Adler Electronics. No "pigeon holes" . . . you're a key professional, handling a variety of COMPLETE jobs from concept to production—full scope for your initiative and imagination. Adler's expanding 300-plus team does a BIG job all year 'round.

- Located in Westchester, 45 minutes from mid-NYC.
- Finest schools, social & cultural facilities—"suburbia".
- Pleasant, informal conditions; generous fringe benefits.

QUALIFICATIONS:

Transistor Circuit: 3 to 4 years min. exp.
Vacuum Tube Circuit: 5 to 10 years min. exp.
Background in VHF, UHF, printed circuitry, and reliability designing, coupled with development know-how in creation of breadboard models.

LOOK INTO OUR FUTURE AND YOURS.

A

Please contact or send resume to:
Adeline Jennings,
NE 6-1621

ADLER ELECTRONICS, INC.
1 LeFevre Lane, New Rochelle, N.Y.

circle No. 37 on Reader Service Card

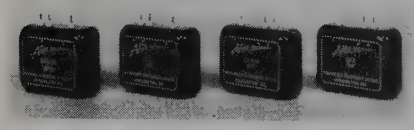
voltages over a wide dynamic range which extends down to a fraction of a millivolt. Unlike mechanical choppers which can only be designed to operate over a narrow and comparatively low frequency range due to mechanical limitations, this transistorized chopper is an inertialess device that can be driven from *dc* to hundreds of kilocycles.

Circle 141 on Reader Service Card

Composite Transistors and Diodes

Advanced Research Associates, Inc. announces a newly developed line of "composite" transistors. According to the manufacturer these transistors feature several thousand percent higher gain, internal thermal compensation and overall gain stability. These units differ primarily from conventional units by employing a greater number of internal junctions, while retaining the same number of external leads.

Circle 135 on Reader Service Card



Printed Circuits

Elco Corp. announces their "Varipak," a printed circuit board enclosure. It is designed to be adapted to any packaging technique utilizing printed or etched circuitry, and to provide maximum density from shelf stacked parts. "Varipak" holds boards and printed-circuit connectors in alignment, and when used in conjunction with Elco's Series 7000 Printed Circuit Varicon Connectors and etched wiring boards, can automatically replace the technician's soldering time of approximately 40 hours per card cage.

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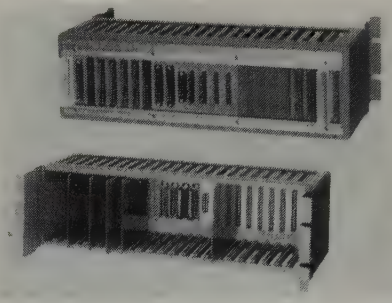
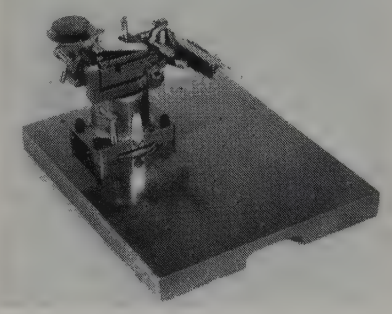


Micromanipulator

The J. H. Emerson Co. produces a precision Micromanipulator for the control of small instruments under high or low magnification. This device makes possible the accurate and rapid control of microtools used in biological research, processing and assembling of electronic parts, or for any other procedure where small elements must be moved, aligned, or worked on under a microscope.

Circle 143 on Reader Service Card



High Grade Silicon

Mallinckrodt Chemical Works has announced the development of a high grade of semiconductor silicon metal. They are now engaged in an extensive market testing program. This product is the result of research carried on in the Mallinckrodt laboratories and pilot plant.

Mallinckrodt silicon meets the highest standards required for the electronics industry.

Circle 111 on Reader Service Card

Technical Sales—Semiconductor Field

Large mideast firm working in rapidly expanding field of ultra pure silicon requires technical salesman. Must be willing to travel.

Degree in physics, chemistry, metallurgy, or electronics preferred. Age—25-35 years old. Previous experience in semiconductor or electronics field preferred.

Send complete resumé, including salary requirements, etc. to Box D9. 300 West 43rd St., N.Y.C., Room 600

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If the cost of metal stampings and wire forms figures in your profit picture, let us give you a quotation on your current components. Send us a sample or blueprint . . . and discover how big savings in time and production costs, big gains in precision and uniformity are possible on small components, when Art Wire tackles the job!

Our engineering staff, our production experience, and our modern high speed equipment are always at your disposal. If you wish to learn more about what a wide and versatile range of shapes and parts we can produce for you—at lower cost than you'd guess—just write for our illustrated folder.

ART WIRE AND STAMPING CO.

29 Boyden Place, Newark 2, N. J.
circle No. 33 on Reader Service Card

New Literature

Two four page folders covering the uses and specifications of two power supply kits have been announced by Electro Products Laboratories.

Circle 150 on Reader Service Card

Two new charts have been published by Fansteel Metallurgical Corporation as a service to industry. One chart shows the melting points of the metals, both in Fahrenheit and Centigrade scales, while the other chart shows the densities of metals, grouped into heavy, medium and light classifications.

Circle 151 on Reader Service Card

The selection of micro miniature relays is made simple by five short steps, as described in a handy two color folder produced by Schweber Electronics. The Guide, graphically illustrated, cuts time to a minimum when selecting micro-miniature relays.

Circle 152 on Reader Service Card

Derivation and Tabulation Associates, Inc. (D.A.T.A.), has published the July 1958 Supplement to the Transistor List of April 1958. This supplement lists new types, as well as those whose characteristics have been altered since the April listing. Types which have become obsolete are also listed.

Circle 173 on Reader Service Card

Stevens Manufacturing Company, Inc. announces a new bulletin on the company's line of Stemco Type S bimetal thermostats designed for use in appliances or for industrial applications. Punched for insertion in standard three-ring binders, the bulletin describes the operating principle and the construction of these thermostats.

Circle 155 on Reader Service Card

International Instruments Inc., announces the publication of a new Preliminary Data Sheet, providing complete information and specifications on the recently developed Model 1145 Expanded Scale D-C Voltmeter. They believe that it provides information of value for all designers of electrical and electronic equipment, where variations in voltage might seriously affect performance of their equipment.

Circle 157 on Reader Service Card

DIRECTOR, SEMICONDUCTOR RESEARCH & DEVELOPMENT

MICROWAVE ASSOCIATES, INC., INVITES QUALIFIED SEMICONDUCTOR SPECIALISTS TO DISCUSS THE DIRECTION OF AN EXTENSIVE EXPANSION OF OUR EXISTING LONG-TERM PROGRAM IN SILICON DEVICES.

THE MAN WE SEEK WILL BE ASKED TO ORGANIZE THE EXPANSION OF THE EFFORTS OF OUR PRESENT GROUPS ENGAGED IN SILICON METALLURGY AND THE DESIGN OF SUCH DEVICES AS DIFFUSED MESA JUNCTION VARACTORS FOR MICROWAVE PARAMETRIC AMPLIFIERS; SILICON POINT CONTACT MICROWAVE MIXER AND VIDEO DIODES; AND JUNCTION TYPE SILICON RECTIFIERS.

HIS ACADEMIC TRAINING SHOULD BE IN A FIELD CLOSELY ASSOCIATED WITH SEMICONDUCTORS AND ON THE DOCTORATE LEVEL. HE MUST COMBINE KNOWLEDGE OF SOLID STATE PHYSICS, SILICON METALLURGY AND SOME ELECTROMAGNETIC THEORY. IN HIS ACHIEVEMENTS SINCE GRADUATION HE SHOULD HAVE DISPLAYED A NOTEWORTHY BLEND OF CREATIVE AND ADMINISTRATIVE CAPACITIES WHICH HAS GAINED HIM TECHNICAL RECOGNITION IN THE FIELD.

PREVIOUS MICROWAVE EXPERIENCE WHILE DESIRABLE IS NOT VITAL, SINCE OUR PRESENT SEMICONDUCTOR STAFF CONTAINS CAPABLE TALENT IN THIS AREA. THIS EXTREMELY IMPORTANT POST REQUIRES A MATURE LEADER WHO CAN GUIDE, PROGRAM, DEVELOP AND STAFF THE GROWING SEMICONDUCTOR PROGRAM OF A COMPANY WHICH HAS GROWN OVER 50% IN THE PAST YEAR AND IS INTERESTED IN CONTINUED GROWTH.

MICROWAVE ASSOCIATES HAS, SINCE 1950, DEVELOPED A STRONG, RESPECTED AND WELL RECOGNIZED POSITION IN THE SILICON SEMICONDUCTOR FIELD. WE HAVE A DEMONSTRATED RECORD OF CONTINUED AND PROFITABLE GROWTH . . . 300 PRESENT EMPLOYEES . . . AND AN ULTRAMODERN PLANT OF 50,000 SQUARE FEET, SITUATED ON A KNOLL OVERLOOKING BOSTON'S FAMED CIRCUMFERENTIAL HIGHWAY, ROUTE 128. IT IS PART OF THE NEW SCIENTIFIC COMMUNITY SPRINGING UP IN THE AREA.

APPROXIMATELY 40% OF OUR EMPLOYEES ARE STOCKHOLDERS. OWNERSHIP ALSO RESTS IN THE HANDS OF AMERICAN BROADCASTING-PARAMOUNT THEATERS INCORPORATED, THE WESTERN UNION TELEGRAPH COMPANY AND THE PUBLIC THROUGH THE SALE OF COMMON STOCK UNDERWRITTEN BY LEHMAN BROTHERS OF NEW YORK.

THE SALARY ARRANGEMENT WILL REFLECT THE CONSIDERABLE IMPORTANCE WE ATTACH TO THIS KEY POSITION AND WILL INCLUDE A LIBERAL STOCK OPTION PLAN. WE WILL DISCLOSE SPECIFIC DETAILS OF OUR OPERATIONS TO QUALIFIED CANDIDATES.

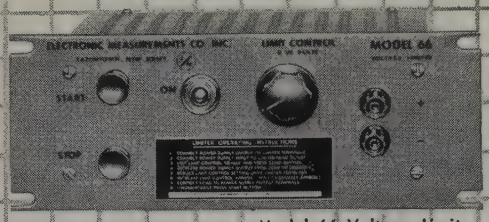
YOU ARE MOST CORDIALLY INVITED TO A CONFIDENTIAL EXPLORATORY DISCUSSION OF YOUR FUTURE WITH US. CONTACT DR. JEROME KORNREICH FOR SUITABLE ARRANGEMENTS.

MICROWAVE ASSOCIATES, INC.

BURLINGTON, MASSACHUSETTS • Telephone: BRowning 2-3000

For further information circle No. 24 on Reader Service Card

Stop transistor burnout!



Model 66 Voltage Limiter

Use your power supply as usual. Set the Voltage Limiter control to any value between 0 and 50 volts. If the pre-set voltage is exceeded, the Voltage Limiter instantaneously clamps the d-c voltage and turns off your power supply. For use with power supplies up to 3 ampere rating. Request Specification Sheet VL 66.

ELECTRONIC MEASUREMENTS CO., INC.

EATONTOWN, NEW JERSEY

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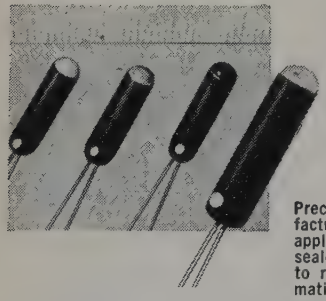


SILICON ZENER DIODES

Precision engineered by world famous manufacturer and performance proved in critical applications. Zener Diodes are hermetically sealed in glass . . . ruggedly constructed to resist shock, vibration and extreme climatic conditions.

Maximum dissipated Power (mW) 200 and maximum temperature 300°F for all types.

Overall dimensions:

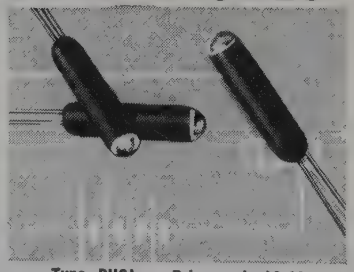
diameter	.16"
length	.59"
leads length	.79"

Type	Price each	Type	Price each
DR 5	$3.40	DR 13	$2.55
DR 6	3.00	DR 16	2.55
DR 7	2.55	DR 19	3.00
DR 9	2.55	DR 24	3.00
DR 11	2.55		

GERMANIUM PHOTO-DIODES

SPECIFICATIONS:

length	.73"
diameter	.18"
sensitive surface diameter	.06"
sensitivity better than	70mA/lumen
no-light current:	
maximum: at 30 volt	20 uA
average: at 30 volt	8 to 10 uA
maximum collector voltage	30 volt
noise (collector voltage —1V) (band 200-2000 C/S	$2x10^{-10}$A
output resistance	3 Megohms
output capacitance	30 pF
3 db band-width better than	.5 mc/s



Type: PHGI Price each: $3.40

Write for detailed specifications

New York's Leading Distributor of Electronic Equipment

Terminal Radio CORP.

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Reader Service Dept., SEMICONDUCTOR PRODUCTS
300 W. 43rd St., New York 36, N.Y.

THIS READER SERVICE COUPON VOID AFTER OCT. 25, 1958

All advertisements, New Prods & Literature are numbered for your convenience

Sirs: Please send me information on the items mentioned in your Sept./Oct. issue which are keyed as follows:

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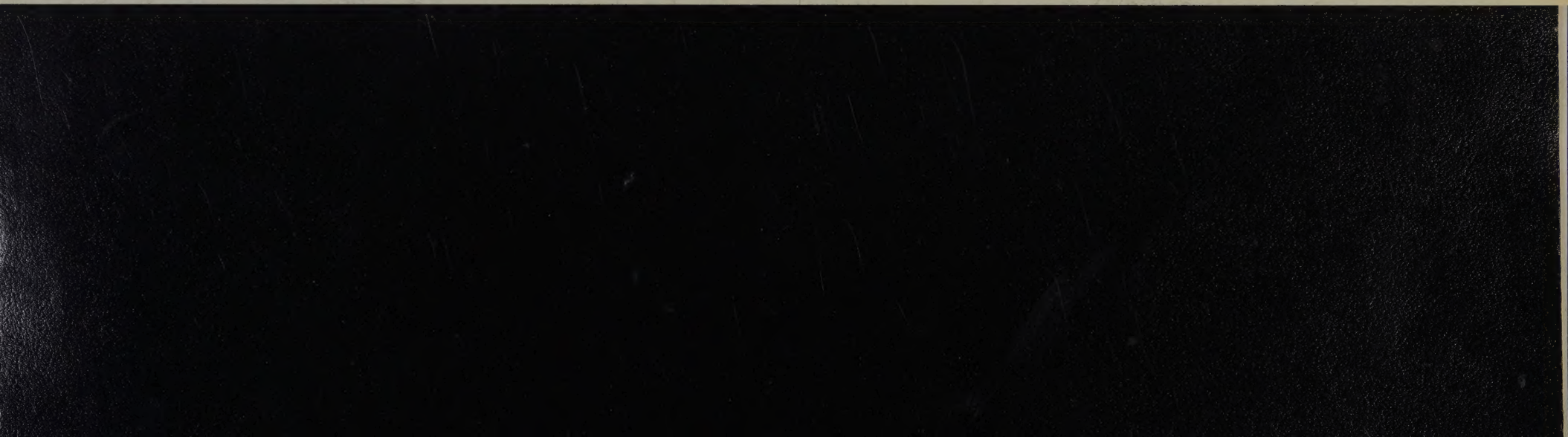

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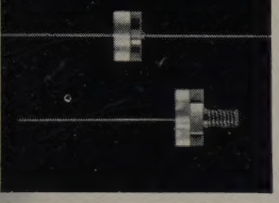

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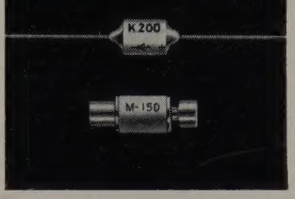

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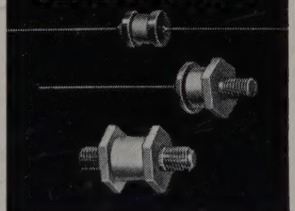

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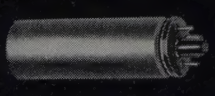

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